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ABSTRACT

This Cooperative Extension Service publication from Mississippi State University is a training guide for commercial pesticide applicators. Focusing on agricultural pest control, this publication includes a full range of topics from uses of pesticides for agricultural animal pest control to the toxicity of common pesticides to fish and bees. Contents include: (1) introduction to pest management; (2) plant disease control; (3) weed control and herbicides; (4) persistence of herbicides in soil; (5) potential phytotoxicity; (6) calibration of pesticide applicators; (7) toxicity of pesticides; and (8) emergency procedure for handling accidental spills of class B poison pesticide chemicals. Within the contents, conversion factors, equipment diagrams, application rate tables, toxicity tables and specific pesticide lists are included. (MR)

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training for certification

Cooperative Extension Service
Mississippi State University

Demonstration & Research Pest Control

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INTRODUCTION TO PEST MANAGEMENT

Pests of various kinds have "pestered" man from the beginning of time. Pests - organisms that interfere with desired goals - include a long list of plant and animal disease-causing organisms, insects, weeds, rats, mice, some birds, and predatory mammals.

Man originated as a hunter of animals and fish and as a gatherer of berries and other foods. During this time, he worried little about pests except for the large predatory animals that might attack him.

As society evolved, families banded together to protect themselves from these wild animals. However, they continued to follow the herds of wild animals and to search for suitable food plants. Their goal - to obtain an adequate food supply in a comfortable climate - was reached when men learned they could tame some animals and grow and propagate some food plants; thus, a crude form of agriculture came into being.

Man could now grow some of his food instead of having to keep moving in search of food. But as more and more plants of the same kind were grown in a relatively small area, insect pests and plant diseases began to develop and portions of his crops were destroyed. He recognized these devastating organisms as "pests" because they interfered with his goals. Pests had become his competitor. Crops and domesticated animals were constantly troubled by insects and diseases; weeds invaded growing crops to choke off their vigor. Records from man's earliest history reveal how these crop plants were damaged by insects and diseases.

Pestilence and famine have always troubled man. Evil spirits were often blamed for these crop failures. Biblical writings say that angry gods were responsible for bringing hordes of locusts down upon the land.

The Roman and Greek god, Robigus, was accused of "raining down blight onto the fields" (the rust diseases of wheat). Diseases affecting rice caused widespread famine in China. An infamous famine that directly influenced the population of the United States was caused by late-blight destruction of the potato crop in Ireland in the middle of the 19th century. Over one million Irishmen starved as a result of this famine and thousands migrated to the United States to become a part of the growth of this country.

Society was in a dilemma - man liked the idea of living in a community and had become used to - and expected - food on his table that he grew in his fields. Even if he wanted to return to a hunting-and-gathering way of life, he couldn't; the population was now too large to support such primitive methods. So man, rather than changing his way of life, decided to fight the pests to save his crops, his stores of food, and his livestock.

It wasn't difficult for early agriculturists to understand how predatory animals, birds, and insects caused damage. Insects could be seen chewing on the leaves, fruits, and seeds of plants. Their bite and sting could be felt. The wolf and tiger were seen killing and carrying off young lambs. Weeds were also soon recognized as the good plants' competition.

Plant and animal diseases were difficult for early man to understand. In most cases, he couldn't see the organism that caused the damage. Only the symptoms were there. It was not until the invention of the microscope and the work of Louis Pasteur that the microorganisms' role in causing plant and animal diseases began to be understood. Until then, diseases were blamed on a variety of reasons, ranging from evil spirits to bad weather. For many plant diseases, bad weather was indeed partially to blame.

For many centuries, mystery surrounded the causes and occurrences of crop failures and pestilence, and the mystical beliefs prevented their cures. A tribe's medicine man was looked upon with awe because he was believed to possess supernatural powers for curing human ailments and animal and plant disorders. His healing concoctions included mud, manures, pulverized bones, organs of animals, minerals, and in later years chemical preparations became part of his wares. For some unknown reason, chemical preparations were believed to have magical properties. Many types of mixtures were used on plants, animals, and humans. Unfortunately, the cure was often worse than the ailment - the plants withered and the animals and people often died from the treatment. However, through accident and good luck, a few effective materials were found.

Pest Control Measures

The first pest control measures were crude. Weeds were pulled by hand, rats and predators were clubbed to death, beetles and worms were picked off and mashed, but plant diseases were left to the medicine man's potions.

Early uses of pesticides were directed mainly against insects; however, "pest-averting" sulfur, introduced about 100 B.C., was used against both insects and plant diseases and is still used to control some mites, mildew, and a few other plant fungi. Arsenicals were used as insecticides against chewing insects as early as 50 A.D. Several plant-derived insecticides, such as heliobore, were used for body-lice control; nicotine was used against aphids. About 1850, carbon disulfide was used as a soil fumigant to control grape phylloxera on the roots of grapevines in Europe. Chemical control of plant diseases got a big boost when Bordeaux mixture was developed in France during the 1880's. Before this, weed control chemicals were limited to salt and arsenicals that "burned" off the foliage. It was not until the 1940's with the advent of selective herbicides, such as 2,4-D, that widespread chemical control of weeds was possible.

As population soared; agriculture expanded. And as the agricultural produce increased, so did the pests. The slash-burn-plant-and-abandon system of agriculture used in the tropics provided a minimum of opportunity for insect and disease pests to develop. However, when crops were grown and livestock grazed on the same areas continuously for many years in favorable climates, pests had good opportunity to build up to harmful levels. Although the populations of pests may still be within bounds of profitable agricultural production, significant annual losses in livestock and crops occur.

The early crops and livestock, in general, were selected from the wild varieties and species in the regions where they were domesticated; however, as man pushed into new territory he took with him plants and animals that had never before been in these new environments. As might be expected, native insects and diseases of minor importance quickly adapted to the new introductions and soon became major pests. Man also carried with him numerous pests from the old homeland into his new frontier. Some developed into extremely destructive pests because the checks and balances provided by insect parasites and predators in the homeland to keep the pests in check were absent in the new environment and the pest population exploded in the new land. A few of these destructive pests brought by man into this country are gypsy moth, European corn borer, Japanese beetle, Dutch elm disease, and chestnut blight. In the case of chestnut blight, the American chestnut had no resistance to the blight fungus. The Asiatic chestnut had evolved in association with the fungus over thousands of years and much resistance was present in Asian chestnut trees.

Mechanized agriculture has compounded some pest problems. Vast acres of the same crop, and often the same variety, can be planted and harvested because of mechanization. The trend has been to either continuous cropping on the same land or to short rotations. With many acres of the same crop and variety, same age, same size, on the same land year after year, troubles are apt to appear. In this situation, if one crop plant is susceptible to a disease organism or an insect, millions of other plants may be equally susceptible.

Chemical pesticides became an important part of modern agriculture during the 1940's. Real concern did not focus on pesticides as pollutants until DDT was used on a world-wide basis after World War II. Some of the major factors that focused the world's attention on the hazards of pesticides to the environment were:

1. Other organisms beside the target species were affected. Other kinds of organisms, in addition to the one for which the pesticide was intended, were either killed or adversely affected. For example, when DDT was applied to a lake to kill mosquito larvae, in some instances fish, turtles, and beneficial aquatic life were also destroyed. The use of a poisoned bait, such as strychnine, to kill mice in an orchard, could also kill any beneficial animal that accidentally ate the bait.

2. Some pesticides are persistent and remain toxic for years. A number of pesticides degrade, or break down into nontoxic materials very slowly. Thus, they create a hazard to many types of organisms long after the initial application. Some of the long lasting pesticides include lead, the arsenicals, mercury, and strychnine. Other pesticides that degrade slowly include some in the organo-chlorine family, such as DDT, aldrin, dieldrin, and endrin.
3. Some pesticides can be stored in the body's fat and tissues for a long time. Small levels of pesticides are excreted with the milk of lactating animals. Low levels of persistent pesticides may also remain on plants and in animals that are eaten by humans and other animals.
4. In the biological concept known as the food chain, some persistent chemicals follow a magnification process in each step up the chain. If DDT were applied to the lake to control the mosquito larvae, the larvae would take up minute quantities of the pesticide; minnows eat the mosquito larvae and store higher levels of the chemical than were in the mosquitoes; small fish eat the minnows; large fish eat the small fish; and at each step up the food chain greater amounts of the pesticide are stored in the body.
5. Living organisms can develop resistance or be tolerant to pesticides. In many instances, insects and disease organisms have developed resistance to pesticides which requires constant shifting to other pesticides to obtain effective control. Weed control chemicals (herbicides) are sometimes so effective in eliminating certain kinds of weeds that other kinds which are tolerant or resistant to the herbicide rapidly fill in the space vacated by the susceptible weeds.

Some disruption of the environment has occurred from the use of pesticides; however, the major concern is what might happen in the future with the continued use of persistent pesticides. Will the chemical levels reach a point where many facets of the environment will be adversely affected? This, plus the accidental poisonings that occur each year, has prompted needed changes in the registration, use, and handling of pesticides and in carrying out pest control programs in general.

Societies' Demands

Society appears to have certain demands pertaining to the control of pests. Basically, they are:

1. Highest priority is given for control of pests to protect the health of people and animals. It is not necessary to describe the black plague epidemic that killed approximately one-third of the people in Europe (two pests were involved, rats and fleas); or the millions of people that die throughout the world each year from malaria and yellow fever (mosquitoes). Local outbreaks of encephalitis (mosquitoes) and Rocky Mountain spotted fever (ticks) caused considerable concern and anguish in communities throughout the United States. Control of rabies: there are many cases each year of rabies transmitted to dogs and even to people through the bites of bats, skunks, and other animals which serve as a reservoir of the virus.

2. Protection of food and fiber from pests. The need for all available food and fiber points up the importance of this demand. Millions of dollars worth of food and fiber are lost annually to insects, mites, diseases, birds, rodents, and weeds during production with losses continuing during processing and storage.
3. Alleviation of nuisance pests is a third demand with a somewhat lower priority. No one likes to be pestered by flies, gnats, cockroaches, etc., flying and crawling about our homes. Nor do we like to have pigeons roosting on buildings and layering the sidewalks below with droppings.
4. Maintenance of a viable environment demands ties with the other three and is what this lesson and the entire course is all about - control the pests, but in so doing, maintain a livable environment. In other words, do the necessary job of managing pests without polluting our environment.

Pest Management Employs Many Control Methods

Future success in controlling pests will be primarily dependent on how well past mistakes can be corrected and both old and new methods used which are not destructive to our environment. Numerous methods are available for controlling pests and each method can contribute some success in preventing or reducing kinds of pests and their numbers. Therefore, combining several of the most effective and practical methods, including pesticides, seems to be a logical approach to pest problems.

An Overview Of Pest Control

Some of the methods or means by which pests are kept in check are summarized below:

1. Natural control is any condition that slows down reproduction and growth of a pest organism and cannot be altered at will by man. The weather, especially temperature and moisture, is the major natural control force. It can encourage or discourage insect and plant disease outbreaks.
2. Cultural control is any manipulation that tends to disrupt the normal association between a pest and its host. Examples are cultivation for weed control and control of planting dates. Planting wheat after the fly-free date has been a standard practice for many years to reduce Hessian fly damage.
3. Mechanical control is the use of special equipment. The results are immediate and positive. A classic example of this method is the fly swatter.
4. Legal (quarantine) control uses procedures that resist the introduction or spread of a pest into an area; such as, active trapping, inspection, and abatement such as the cooperative efforts between federal and state agencies in the gypsy-moth program.

5. Biological control is the direct or indirect use of living organisms to reduce the number of pests below a level of economic importance. Examples are hawks catching mice, lady beetles eating aphids, and one fungus antagonistic to another.
6. Chemical control is the use of chemicals to suppress a pest population. We normally think of chemical control as toxic materials that kill weeds, insects, rodents, and plant-disease organisms; however, this is only part of the chemical arsenal. There are also chemical repellents, attractants, sex lures, hormones, growth regulators, etc.

Chemical pesticides usually provide only temporary reduction of pest numbers and involve certain risks to nonpests and beneficial organisms. Some pesticides can also be a potential hazard to the environment. However, chemical pesticides usually provide quick results, are easily manipulated, are usually readily available, and are economical under most conditions.

7. Genetic control is control through the use of resistant or tolerant varieties.
8. Integrated control is the combination of cultural, mechanical, biological, and chemical control in a compatible relationship and forms the basis for a total pest management plan. An example would be the control of the alfalfa weevil on alfalfa. If weevil damage becomes serious, the field is sprayed with a selected pesticide that will bring the pest numbers back down to a tolerable level, but in so doing will have minimal adverse effect on the weevil parasites.
9. Pest management is the use of a number of effective control measures coordinated for overall crop or animal protection so as to reduce pest numbers to a low enough level where they cause little economic damage.

Pest Management

Comprehensive pest management can work. There are three major goals:

1. To reduce the amount of pesticide being released into the environment. This does not mean the use of pesticides should be stopped; however, those pesticides used should be carefully selected for each situation. The risk-benefit equation for each situation must be carefully weighed and when pesticides are needed only those that will do the job with the minimum of pollution or disruption should be used.
2. To reduce or at least not greatly increase the cost of controlling pests. Cost figures compiled from pest management programs now in progress indicate that the number of pesticide applications can be reduced, thereby lowering both the amount of pesticides used and cost of application.

3. To produce a good yield of acceptable quality, in the case of a crop, or to give acceptable results in other situations.

It is an obvious conclusion that any pest control program that reduces pollution resulting from persistent and toxic substances and lowers or at least not greatly increases the cost of doing the job with acceptable results will be quickly adapted. However, as systems of pest management become more diverse and technical problems become more complex, more technical knowledge is needed.

Experience with cultural, mechanical, chemical, biological, and other methods of controlling pests has shown us that each method has limitations in its effectiveness and practicality. Limitations include the time available to obtain control (the crop may be destroyed before the job is done), manpower available, costs, etc. Another problem that must be considered is the expertise and time needed for proper management of such programs. The money saved on reduced spray applications and lower pesticide use may be needed to pay for technical knowledge of the program.

MANAGEMENT OF COMMON INSECTS AND MITES

In the eastern United States, there are approximately 300,000 different kinds (species) of insects, mites, spiders, and related arthropods. No one can be expected to recognize all these species, and no one needs to -- there are only about 100 species that are of economic importance on an average farm. When you consider the different insects and mites that attack animals, damage crops, eat stored foods and feeds, ruin buildings, and pester people, the number is small and many of these pests can be readily recognized and identified.

This vast number of insects, mites, spiders ticks, etc., can be divided into three categories according to their economic importance:

1. The first and largest category includes those species which are of only minor importance to man. Approximately 99 percent of the species fall into this category and are the ones that "take up space" and supply food for birds, fish, and other organisms.
2. The second rather small but important category includes the beneficial insects and mites. In this group are the parasites and predators that feed on destructive insects and weeds; for example, lady beetles, ground beetles, tachinid flies, and numerous tiny, parasitic wasps. Also in this category are the pollinating insects, such as bumblebees and honeybees. Without the pollinators you would be without some fruits, vegetables, and forage.
3. The third category is for the destructive insects -- the category that usually comes to mind when insects are mentioned. However, this category fortunately includes the smallest number of different species. In this category are the caterpillars, beetles, plant bugs, and aphids that destroy crops; the mosquitoes, lice and flies that attack animals; and the weevils, termites, and borers that destroy stored products and structures.

Diagnosis of Insect Problems

The way in which an insect feeds or inflicts damage to a plant or animal, thereby producing typical symptoms, often provides a reliable clue to the identification of the pest.

Damage to plants is found in many ways, with all parts of the plant subject to attack.

1. The most obvious damage is the destruction or actual eating away of the leaves and foliage. This damage is usually done by either the larvae or

caterpillars of moths and butterflies or by adult beetles and their larvae. The imported cabbage worm that chews up cabbage leaves and the armyworm which frequently eats the leaves of corn and small grains are examples of caterpillars that are destructive to the foliage.

2. Another easy-to-see damage occurs to fruits or seeds. The worm in the apple is probably the immature stage or larva of the codling moth; the fat, white worm in the plum is the larva of the plum curculio; and the active, dirty-white worm found in bell peppers is probably a larva of the European corn borer.
3. Some insects do their damage by working their way into the stem of the plant, thus weakening the plant internally. Common examples of this type of insect are the European corn borer, the common stalk borer, and apple tree borer. Infested stalks often wilt or may break due to the weakened stems.
4. There are usually several symptoms caused by sucking insects, such as aphids, spittlebugs, leafhoppers, whiteflies, and scale insects. Aphids, whiteflies, and soft scales not only weaken the plant but they also excrete honeydew which drops onto lower parts of the plant. A black sooty fungus soon develops in the honeydew giving the plant the appearance of being dusted with soot. Spittlebugs can easily be identified by the small masses of spittle-like bubbles that surround the feeding nymphs. In the feeding process of leafhoppers, some of the plant's food-carrying channels are blocked off resulting in stunted growth or dead areas of the infested leaf. Some of the species of aphids and leafhoppers are also known to be carriers of some plant diseases.
5. Some insect damage is found when young plants are cut off near ground level. This symptom is usually associated with cutworms, the larvae of a group of moths.
6. Among some of the most difficult insect pests to identify by plant symptoms are those that damage the roots and underground portions of the plant. Root damage causes various symptoms depending upon the plant species and weather conditions. Most plants with root damage show lack of vigor and off-color. Alfalfa plants with damaged roots may show excessive heaving during the winter, whereas corn may fall over the then "goose neck" as the plants right themselves. Symptoms in other kinds of plants are usually less obvious. Some of the common soil pests are the seed and root maggots (larvae of certain kinds of flies), southern corn rootworm (larvae of a small yellowish-green beetle), wireworms (larvae of click beetles), and white grubs (larvae of June beetles).

Insect pests of livestock are primarily of four types:

1. Those which suck blood, such as the biting flies and biting lice;
2. Those which pester and annoy animals, such as face flies and house flies;

3. Those which destroy tissue and act as a parasite within the body of the animal, such as ox warble of cows, nose bot of sheep, and bot fly of horses; and
4. Scab mites, which feed on blood and lymph near the skin surface, with the affected skin showing as rough and scabby with little or no hair remaining.

Planning Pest Control Programs

In the discussion of insect pest management, only the beneficial and the destructive insects will be considered, since they are the ones that are of direct importance to you. In developing a pest control program for a particular crop or type of livestock, follow a few basic steps in planning.

Step 1. Identify the insect or insects involved. The major insect pests to farm crops and animals are not very numerous and can soon be recognized. You will seldom have any trouble identifying the common insect pests that occur in your area, such as the European corn borer, alfalfa weevil, boll weevil, Southern pine beetle, cattle lice, etc.

It is the unusual insects, or those that are new to your area, that will be most difficult to identify and for which additional help may be needed. You can get assistance from your local county Agricultural Extension Agent. He will either identify the pest or contact a university specialist for the answer. There are also a number of competent fieldmen affiliated with agricultural supply dealers that may help you in insect identification.

The college of agriculture's Cooperative Extension Service, one of which is located in each of the 50 states, prepares publications on most of the major pests affecting crops and animals in each state. These publications are available through the county agent's office near you. Their office is listed under "Government Agencies" in your telephone book.

The important point is to make a correct diagnosis of the cause of the problem - and the pest - before attempting any control measures.

Step 2. Select the appropriate method or methods on control. This can be a rather easy process or a very complex one that should be planned a year or more in advance. Perhaps the best way to understand what types of planning are involved is to take the example of the major insect control problems on two farm crops. Cotton has rather complex pest problems, while those of soybeans are relatively few.

First, identify the problem by listing the major insect pests of cotton in your area. The most destructive pest over a period of years has been the boll weevil. A second insect pest is the bollworm. Others include the thrips, cutworms and aphids. Five insects are listed, but the latter three have not caused any major losses to the crop. Bollworms appear to be stabilized in the southern United States with high populations and serious damage

limited to localized areas. Parasites are present throughout the area. Aphid invasion of cotton fields is unpredictable. Infestation levels are seldom uniform among fields and infestations vary widely among localities within a state, as well as from year to year.

What types of control measures can be used to manage these five pests to the best advantage? Natural methods are always available and result in ups and downs of pest numbers, but they cannot be completely controlled and therefore are never reliable.

How about the cultural control? The use of early planting dates will allow the crop to be harvested early thereby interrupting a part of a generation. This practice coupled with stalk destruction will reduce the number of weevils entering diapause.

Biological control will control several of these insects and diseases normally do a good job in keeping cabbage loopers in check. Several parasites of the bollworm are established and are helping hold down this important pest. There are no known biological agents that effectively control the boll weevil.

Chemical control (insecticides) is available for all pests. Several questions must be answered before a pesticide should be used:

1. Is it needed?
2. Which insecticides will control the pests without injuring the others?
3. When should spray be applied if it is needed?
4. How many acres need treatment? and
5. Which insecticides will do the best overall job without leaving any residue on the crop when harvested?

How many insect pests per plant or how much damage can appear on a plant before chemical protection is needed or before it is financially justifiable? The term used to describe this situation is economic threshold. After many years of research and experience, the economic threshold for boll weevil is reached when 10 percent of the squares show punctures then make 3 applications 4 to 6 days apart and continue as needed.

These are three obvious alternatives that growers can select from to control pests. As expected, each alternative has its advantages and disadvantages. Keep in mind that this approach to the solution of the pest problem is an approach that can be used to try to solve any pest problem of any crop.

Alternative No. 1. This alternative is to do nothing. The grower may talk about treating for pests, but when the time comes for action, the crop looks fairly good so he does nothing.

Advantages:

- a. This alternative saves the grower the cost of a spray application.
- b. There will be no hazard to beneficial parasites or predators and certainly no chance of pesticide pollution of the environment.
- c. If the pest population is nil, the crop will escape damage.

Disadvantages:

- a. He has a good chance of losing a substantial quantity and quality of his production.
- b. Lack of treatment, if needed, will result in weakened plants and reduce production.
- c. Lack of insect control could put the grower out of cotton production.

Alternative No. 2. This alternative is one of prevention. This grower follows a definite spray schedule regardless of the insect populations in the fields.

Advantages:

- a. Such a schedule will practically eliminate insect damage and will provide an opportunity for a potentially high yield.
- b. The grower should have ample time to secure spray material and build spraying time into his work schedule.
- c. A preventive schedule will take the guesswork out of the grower's insect problem.
- d. The schedule might control other pests that are present in the field at the particular time sprays are applied.

Disadvantages:

- a. This spray schedule will be high in cost.
- b. Some of the spray applications would almost certainly not be needed.
- c. The additional unneeded applications increase the hazards to beneficial species without any resulting benefit.
- d. Fixed-spray schedules that call for the application of an insecticide, whether needed or not, definitely increases the opportunity of the pest to develop resistance to the insecticide.

Alternative No. 3. This alternative approaches the principles of pest management. The grower monitors insect populations in his crop.

The grower uses a registered insecticide only on those fields when and where insect numbers warrant their use.

Advantages:

- a. This type of control program practically eliminates insect damage and provides opportunity for a potentially high yield.
- b. Unnecessary spray applications would be eliminated resulting in less use of insecticides and reducing application costs.
- c. Good monitoring methods pinpoint fields that need protection and give optimum timing to apply the insecticides.
- d. Since all fields will not need spray protection, the amount of insecticides used on the farm will be reduced and a reservoir of beneficial insects will be maintained in the untreated fields on the farm.

Disadvantages:

- a. Expertise in monitoring fields and understanding economic thresholds must be developed.
- b. Most, if not all, of the costs saved from fewer spray applications can be spent on monitoring and management of the program.
- c. Buying insecticides and planning the work schedule for spraying will be uncertain and on short notice.
- d. Some growers will be reluctant to adopt this alternative due to a lack of confidence in their management knowledge.

Step 3. This step is the proper use of the selected control methods. Controlling insects costs money, so you must get the best results possible out of the control measures you use. To do this, some basic facts about the life cycle and biology of the pest must be learned so control measures can be applied at the optimum time. Some of the things you need to know about the insect pests are: What stage or stages of the insect cause damage? Is it the larval stage, as in the European corn borer and cabbage worms; is it the adult stage, as for stable fly, striped cucumber beetles, and house fly; or is it both the immature and adult stages, as in Colorado potato beetle, Mexican bean beetle, and elm leaf beetles?

When is damage expected to occur? Is it in June from an insect that has only one generation per year. Is it in June and again in August by an insect that has two generations per year. Or can you expect a problem all season long from a pest that has many generations per year, such as the house fly, corn earworm and aphids?

When insecticides are selected as the appropriate control method, immediate consideration must be given to their safe and proper use. Always keep in mind that insecticides are toxic to at least some insects and most of the commonly used insecticides are toxic to both destructive and beneficial kinds. In addition to being toxic to insects, insecticides are usually toxic to man, domestic animals, and wildlife. Insecticides vary considerably in their toxicity (this topic will be discussed later).

Since most insecticides are potentially hazardous to bees, parasites, and other beneficial insects, applications should be made either when such insects are not active or should be made in such a manner that the insecticide will have minimum effect on the beneficial organism.

For example, don't spray fields if the plants are in full bloom unless it is absolutely necessary to save the crop from destruction. If spraying must be done, then apply the insecticide late in the day after foraging bees have left the field.

Avoid the use of highly toxic insecticides near pastures and around buildings where air currents may drift some of the insecticides onto animals or onto forage in nearby pastures.

How, where, and when should the insecticide be applied to get the best results, to be practical and economical, to avoid contamination of food, feed, water, etc., and to have the least adverse effects on the environment? For example, the use of a registered insecticide applied as a granular formulation to the soil at planting time provides effective control of corn rootworm and is both practical and economical to use. By using a granular formulation, the toxicity exposure to the operator is minimal and by applying the insecticide into the soil there is little chance of immediate environmental pollution. Attempting to control the corn rootworm adult beetles in August and September as they collect on the corn silks, with spray applications of an insecticide is not practical unless they interfere with pollination. As you can see, such a use of an insecticide will not offer effective control of the problem because it is applied too late to protect the growing crop and will not kill enough of the beetles to avoid damage next year. It is neither practical nor economical due to the height of corn and number of applications necessary. The insecticide will be hazardous to bees since it will be applied when the corn plants are shedding pollen and bees work corn during this time. Drift and air pollution from the sprayed insecticide are greater than from the soil application.

The proper use of the selected control method can be summarized with the word "SEE." See to it that SAFETY precautions to the operator, animals, and environment are followed. See to it that the method is used EFFECTIVELY to get the best control possible. See to it that the control method used is EFFICIENT. You can't spend more for pest control than the value of the commodity being protected.

Step 4. A final and obvious step is to measure the results. It is usually fairly easy to determine if the pests were satisfactorily controlled, if the measures were only partially effective, or completely ineffective. Any undesirable side effects resulting from the control measures should be noted and evaluated. Some undesirable effects may show up promptly while others may not surface for several years.

With constant evaluation of your insect control programs, you can sort out those that are not effective, economical, too hazardous, or even detrimental.

PESTICIDES FOR AGRICULTURAL ANIMAL PEST CONTROL

Pesticide Toxicity

Pests of agricultural animals can weaken animals, thereby causing them to be unthrifty, predispose them to diseases and can even cause their death. Pesticides will protect animals from pests; however, all pesticides are poisons and can be toxic to warm-blooded as well as cold-blooded animals. For this reason, recommended pesticides must be applied properly to prevent injury to animals.

Individual animals can show toxicity to certain pesticides and materials contained in pesticide formulations. Applicators should always be aware of this. Sensitive animals should not be treated or should be treated only with pesticide formulations non-toxic to the animal. Brahman beef cattle can show sensitivity to some organic phosphate insecticides. For this reason, organic phosphate pesticides should not be applied to these animals if so indicated on the pesticide label. Poisoning is usually exhibited as excessive salivation, eye watering, defecation, urination and muscle twitching.

Animals which are under stress or which will be put under stress should not be treated.

Pesticides should not be applied in combination with other pesticides unless so stated on the label.

The skin of some horses is extremely sensitive to various pesticide formulations. Before treating horses with pesticides, it is recommended that a small patch of skin on each animal be treated with the pesticide formulation approximately 24 hours before the entire animal is treated.

Residue Potential

Most agricultural animals are raised for the human food products they produce. For this reason, it is extremely important that pesticide residues not be allowed to accumulate in illegal amounts in edible tissues. Producers should apply only approved insecticides to animals which are being finished for slaughter or are producing edible products such as milk. Some insecticides are eliminated slowly from animal tissues. Others are quickly eliminated. For this reason, intervals between application and slaughter or use of eggs and milk as human food should be strictly adhered to. For these reasons, label directions should be followed to the letter. Failure to do this can result in animals being confiscated and responsible individuals prosecuted.

Pesticide Hazards

Pesticide Formulations. The pesticide formulation to be used must be taken into consideration when treating agricultural animals. Sprays are generally suited for treating most animals, except, when temperatures are below freezing it is not advisable to spray or dip livestock. This can predispose them to diseases such as pneumonia. Insecticides applied during very hot, still days may cause damage to treated animals. When applying ready-to-use oil sprays, be careful not to allow the oil to penetrate the animal's hair so it comes in contact with the skin. Some types of agricultural animals show toxic effects when oils are applied to their skin.

Individual animals can show allergic responses to certain pesticide formulations. Applicators should be aware of this and be prepared to apply remedial measures such as removing the insecticide from the affected animal. Sensitive animals should not be retreated unless a suitable pesticide formulation can be used. Four-on and dust pesticide formulations are recommended when treating animals in freezing temperatures because they do not add excessive amounts of moisture to the animal.

Pesticide Application Techniques. When treating agricultural animals for external parasite control, it is important that insecticides be placed so that contact with the external parasites will occur. The selection of an insecticide delivery system will depend upon the animal to be treated and the pest to be controlled. For example, when treating animals for lice, mite and tick control, penetration is normally very important. Use 100-200 pounds of pressure when applying pesticides for control of these pests. Pesticides kill only the mites and lice, not the eggs, so retreatment is normally needed to control newly hatched pests.

Grub spray treatments should be applied in such a manner that the skin, not just the hair of the animal becomes thoroughly wet. Spray pressures of 200-400 pounds per square inch are recommended depending on the thickness of the animal's coat of hair. Apply treatments after egg laying has been completed.

Power sprayers, knap-sack sprayers, compressed air sprayers and rubbing devices such as back rubbers and face rubbers are satisfactory for applying liquid insecticides to agricultural animals. Rubbing devices usually consist of a pesticide reservoir and a material on which animals rub that acts as a wick to pull the insecticide from the reservoir, thereby keeping the rubber saturated with insecticide. Homemade rubbing devices normally consist of burlap bags rolled around chains or wire. The insecticide is poured on the burlap bag to keep it charged. Automatic sprayers are commonly used to apply insecticides to animals on a frequent basis. They are commonly used to treat dairy animals as they exit milking parlors.

Dusts may also be used for control of some external parasites on agricultural animals. They may be applied by hand or in suspended, self-treatment dust bags.

Systemic insecticides are those insecticides which are picked up by the animal's blood system and transported throughout the animal's body. They can be applied as pour-ons, spot-ons, sprays, feed additives and in dipping vats. Some systemic insecticides are very effective against grubs, horn flies and lice.

Age and Size of Animals. Even when animals are healthy, their age and size are important considerations when applying pesticides. Many insecticides are applied according to the size of the animal with less being applied to small animals and more to large animals. Many applications are applied to point of run off. Generally, this is the amount of insecticide recommended for use on animals. Systemic insecticides and ready-to-use oil sprays must be applied in exact amounts for adequate control of pests and prevention of injury to animals.

Young animals, especially those under six months of age, should not be treated when information on the pesticide label specifically prevents application to younger animals.

Extent of Treatment. Many pests on agricultural animals can be controlled with very small quantities of pesticides when applied to specific areas on the infested animal. For example, when treating infested wounds on animals, only treat the wound and immediate surrounding area.

When treating livestock for fly control, it is usually more efficient to treat animals daily with small quantities of pesticides. If rubbing devices such as back rubbers and dust bags are placed where animals cannot avoid them, they will treat themselves daily with small amounts of insecticides, thus obtaining good pest control with less material. The application technique which will afford adequate control with the least excitement of treated animals and least contamination of the environment should be utilized for the most effective, economical and safe control of agricultural animal parasites.

PLANT DISEASE CONTROL

Disease organisms include certain fungi, bacteria, viruses, and nematodes. In order to control these disease organisms, you must know the organisms' life cycles and their behavior on crops. In every instance, knowledge of the culture of the crop and the diseases that affect it are essential for development of a practical, safe, hazard-free control program.

Holding plant diseases to acceptable levels for crop production or maintenance of ornamentals, landscape, and vegetation plants is a complex problem. Chemical pesticides play a large role in the control of many plant diseases. In most instances, chemicals should be used in conjunction with all other feasible methods of disease control.

Fungi As Disease Organisms

Most agricultural plants are susceptible to attack from many different fungi. For example, potato, bean, and cotton could be attacked by at least 30 different disease organisms. On a worldwide basis, fungi alone cause losses amounting to hundreds of millions of dollars a year. Any part of a plant's roots, stems, leaves, flowers, fruits, or seeds may be attacked. Fungi also attack harvested products, such as fruits, bulbs, rhizomes, and wood - in transit and in storage. The control of fungus disease organisms is greatly complicated by their diversity and variability. Some have spore stages specialized for spreading via air, in water, or in the soil; still others, because they produce resting seedlike spores, have survival periods of many years.

Some fungi have the capacity to penetrate healthy tissues directly, by means of a peg from the short germ tube of a spore. In other instances, the fungus is transported by a carrier, such as an insect, and then introduced into the plant. For example, the odor of the oak wilt fungus as it grows between the bark and the popwood attracts certain beetles that pick up spores that cling to their bodies; these spores are introduced into healthy trees on which the beetles feed. Some fungus organisms attack many plant species; others may be restricted to one. It is important in disease control to know which plants the disease organisms will attack.

Fungal attack produces a variety of plant symptoms. They may cause blights and rots on leaves, stems, fruits, and roots. When fungi invade roots, stems, and fruits abnormal growths or galls often result, such as club root of cabbage and stemgalls on conifers. Other symptoms are stunting from root infections and sudden wilting induced by fungi that plug the water-conducting tissues.

Many fungi move from plant to plant by spores. These spores vary in form and size. The red-spore stage of the wheat rust fungus moves many miles on air currents. Spores of other fungi may move only a few inches or feet by splashing rain. The spores of some fungi are exceptionally well adapted to survive under adverse growth conditions.

Spores of certain species of *Fusarium*, a root and wilt disease organism, remain alive in soil several years in the absence of a suitable host plant. Foliage-invading fungi, however, are typically shortlived and die when the infected foliage or stem tissues that sustain them rot away. Fungus spores are usually produced in tremendous numbers, and most of them do not find a host to attack. Spores suited to movement by water or by air currents are formed above ground. Water or high humidity is almost always essential for the active growth of fungi. Most spores will not germinate unless the relative humidity is 96 or 97 percent or higher, and many require wet leaf surfaces.

Bacteria

The number of major diseases caused by bacteria, in contrast to those caused by fungi, is relatively small. Nevertheless, certain bacterial diseases, such as fire blight of pear and apple trees, have been highly destructive and have resulted in much damage to these orchard crops. A major portion of the decay and spoilage of fresh fruits and vegetables in transit, storage, or markets is due to soft rot bacteria.

Species in all major families of the higher plants can be attacked by one or more kinds of bacteria. Certain soil-inhabiting bacteria, such as the crown gall and soft rot bacteria, affect a wide range of plant species. Only a few bacteria cause major diseases of forest or shade trees.

In most cases, the mechanisms by which bacteria cause disease are not well understood. Enzymes, as well as toxic materials, released from the bacteria readily come in contact with the plant tissue. Certain foliage-invading bacteria produce yellowing, and large yellow halos may surround small dead spots. In tobacco wildfire, for example, yellowing is caused by a bacterial toxin that interferes with the chemistry of the cell and indirectly affects chlorophyll (green pigment) production.

Since bacteria that induce plant disease are not sporeformers, they usually die when carried by the wind as isolated cells. Most foliage disease bacteria are therefore dependent mainly upon wind-driven rain for spread from plant to plant. Bacteria in vast numbers may ooze out of breaks in the plant tissue or through bark and leaf pores and be spattered or carried in rain droplets to nearby plants.

A grower may also spread bacteria during cultivating or harvesting operations, particularly if the foliage is wet. Fire blight of pear and apple, for example, may be spread on pruning tools.

Insects can spread certain bacteria as well as make the wound through which infection occurs; wilt of cucumbers, pumpkins, and squash is carried by a cucumber beetle. A wound need not be involved in the spread of some bacteria, such as fire blight, which may be carried by bees and introduced into blossoms.

Bacteria, particularly those that cause foliage diseases, usually survive in plant tissues, frequently within seeds. The organism causing bacterial blight of cotton survives in and on the seed. In the fire blight of pear and apple, bacteria survive in the inner bark tissue near tree cankers.

The major difference between fungi and most plant disease bacteria is the speed of infection. For most leaf fungi, fungus spore germination requires several hours. Foliage-invading bacteria are tiny enough to enter rapidly through natural openings or to be introduced into wounds such as those caused by insects or by cultivation and harvesting equipment. Such direct entry enables bacteria to escape the killing effects of chemical pesticides. Furthermore, many of the newer organic fungicides are not toxic to bacteria. Few bacteriacides have proven to be practical and effective in controlling bacteria without injuring crop plants.

Viruses

Viruses multiply only inside living cells and few living organisms are immune from viruses. Man, domesticated and wild animals, insects, higher plants, bacteria, and fungi can all be attacked. Practically all species of plants may also be attacked by one or more viruses.

Viruses cause many symptoms in plants. Sometimes they kill the plant. More often they cause lesser damage, which results in reduced yields and poor quality products. Most virus diseases fall into two clearly defined groups: the mosaics, which cause mottling and spotting of leaves; and the yellows, which chiefly cause yellowing, leaf curling, dwarfing, or excessive branching but little or no mottling or spotting.

Viruses can be spread in a number of different ways. Many of the mosaic-type viruses can be transmitted mechanically by rubbing juice extracts from diseased plants onto the surfaces of leaves of healthy plants.

All viruses that spread through the plant system can be transmitted by grafting. Vegetative propagation of plants, such as fruit trees, result in the spread of many viruses. Most viruses invade all parts of the host plant; therefore, when buds, scions, or other vegetative parts of diseased plants are used for propagation, the new plants are usually also infected. Tree fruits, strawberries, potatoes, sweetpotatoes, and other crop plants that are regularly vegetatively propagated are likely to carry several viruses that have accumulated in the planting stock over the years.

Insect carriers spread many plant viruses. Depending on the virus, carriers may be leafhoppers, aphids, whiteflies, thrips, beetles, or other chewing insects. After certain viruses are picked up by the insect carrier through feeding on diseased plants, they may persist in the insect and sometimes even reproduce themselves, whereas in other instances the insect is able to transmit the virus for only a short time. A few viruses are transmitted by mites. Some soil-borne viruses are spread by nematodes, while others are spread by certain fungi.

After a plant becomes infected with a virus, there is usually no economically feasible way to cure it. Methods of control, therefore, center on preventing spread of the virus, or by developing varieties immune or resistant to the virus disease.

In some instances, when the spread of a virus is slow, the use of virus-free planting stock for establishing the planting - an approach used to control many virus diseases of tree fruits, grapes, strawberries, and raspberries - is very effective.

Reducing the population of insect carriers with insecticides has given at least partial control of some virus diseases.

In many cases, disease resistance has been effective in controlling virus disease. For example, resistance to corn stunt and maize dwarf mosaic viruses have made the culture of cotton possible in areas where the disease formerly threatened to eliminate the industry.

Nematodes

More than 9,000 species of nematodes have been described, yet the unknown species still probably outnumber the known. Nematodes are distributed throughout the world in a wide variety of environments. They include animal and human parasites, plant parasites, and free-living forms.

The symptoms of nematode damage to plants are not distinctive. Since the most common and important damage occurs to roots, the above-ground symptoms often closely resemble those of any other poorly functioning root system. Thus, it is rarely possible to recognize a nematode problem without root examination and soil nematode analysis.

Nematodes are small, eel-shaped, unsegmented worms which move with a snake-like motion in water. The mouthparts of all nematodes parasitic to crop plants include a spear - a needlelike apparatus capable of puncturing plant cells. Spears of most plant parasites are hollow, and saliva is injected through them into plant cells. Cell contents, partially dissolved by saliva, are then ingested by the nematodes.

Plant-parasitic nematodes may be divided into two groups, internal and external feeders. The internal nematodes enter and feed inside plant tissue; the external remain outside and feed on surface cells. Nematodes from both groups occur on both above-and below-ground plant parts.

Root feeding destroys roots as well as impairs the uptake of water and minerals in the remaining diseased roots. Root-knot nematodes, which are worldwide in distribution, cause some of the most important plant diseases, particularly in warmer climates and in greenhouses. Salivary excretions from the feeding of these internal nematodes cause the formation of large cells that in turn result in swollen, distorted, and knotty roots.

The internal-lesion nematodes move throughout the outer portion of the host root, feeding periodically and laying eggs. This movement and periodic feeding results in the death of scattered root cells, and often in the destruction of nonwoody roots.

The external feeders feed from the surface of the root by inserting long spears into the outer cells. In general, their complete life cycle takes place at or near the root surface. Nematodes are known to transmit several soil-borne viruses.

Understanding Disease Spread

Plant diseases caused by microorganisms are contagious. In order for diseases to spread, sources of these organisms must reach healthy plants and establish new infections. These sources are called inoculum. Inoculum is any material that is potentially capable of producing infection. It may consist of virus particles, bacterial cells, fungus spores, fungus threads, nematodes, etc.

In the typical spread of a plant disease, inoculum is produced in or on the infected plant by the disease organism. This inoculum is then released and can come in contact with a susceptible plant. Usually, a large proportion of the inoculum dies. Only a very small fraction of the total inoculum reaches a susceptible plant and only a fraction of this succeeds in infecting the plant and causing disease. A single kernel of smutted wheat contains from 2- to 12-million spores of the smut fungus. A single gall to the cedar-apple rust may produce millions of spores.

Each disease organism has a characteristic rate of reproduction. In some, the inoculum is produced only once for a short period during the season. Other diseases, such as apple scab and late blight of potatoes, produce new sources of inoculum many times during the season.

Sources Of Inoculum

Inoculum may originate from a few or many diseased plants; it may be produced inside the plant, at the plant surface, on plant refuse, or on organic matter in soil, depending upon the nature of the disease organism. Viruses and bacteria multiply within their hosts. However, many fungus organisms characteristically reproduce from infection centers on the plant's surface. In addition, many diseases live and reproduce in soil, on weeds, or on other plants of lesser value than the crop in question. Inoculum may be found in such locations for a long time and be a reservoir of inoculum that is a threat to a crop.

Johnsongrass that grows adjacent to corn fields may be a reservoir of the corn stunt virus of the Southern United States.

Chemical control of weeds that serve as hosts for viruses sometimes controls the spread of viruses to crops.

With soil-borne disease, the transfer of inoculum within soil occurs slowly and over short distances; however, with flowing water transfer may be rapid and occur over considerable distances. Irrigation and flood water can spread inoculum. Man can also spread soil-borne inoculum by moving soil on farm machinery from one field to another or nursery stock from one location to another.

Inoculum can travel rapidly through the atmosphere. Air-borne spores can spread through a field in a few days. Each type of disease organism is adapted to dispersal in a characteristic way. Principal ways that inoculum spread are by air, water, plant debris, insects, animals, and man.

General Approaches To Plant Disease Control

Control of plant disease is the prevention or reduction of disease. You can sometimes control a disease by using a single procedure, but satisfactory control of most diseases requires multiple control methods. A well conceived control program should consider the characteristics of the disease organism and the crop, the cultural and climatic conditions under which the crop is grown, and a knowledge of available disease control procedures.

Avoidance Of Sources Of Disease Organisms

Choice of planting site. The choice of a suitable planting site is important in order to avoid fields infested with root-infecting organisms, such as those causing *Verticillium* and *Fusarium* wilt, or to avoid fields containing crop residues that can serve as a source of inoculum for air-borne spread.

Choice of planting date. Choose planting dates to provide good environmental conditions (temperature and moisture conditions) that are more favorable for growth and development of the crop plant than of the disease organism.

Use of disease-free planting stock. Disease-free planting stock, grown in a disease-free area or in a certification program, provides one of the most effective means of plant disease control for seed, tuber, or plant-borne disease organisms.

Exclusion Of The Disease Source

Disease organisms may be excluded from a crop production area by treating plant materials, by inspection and quarantine, and in some cases by eliminating carrier insects.

Treatment of plant materials. Seeds, tubers, corms, and other propagative parts of plants can be treated by heat, gases, or chemicals, to destroy disease organisms and thus prevent both direct injury to plant parts and introduction of disease organisms into a new location.

Inspection and certification. Inspection of plant propagation material, followed by certification that they are free of disease when marketed, instills confidence in intrastate and interstate shipments.

Exclusion or restriction by plant quarantine. The purpose of plant quarantines is to prevent the spread of disease organisms from areas where they are present, to areas where they do not occur. A quarantine is justified only if there is little chance of an organism being spread naturally from one area to another.

Elimination of insect carriers. Many plant disease organisms are carried by insects. If the insect carrier can be effectively reduced, the chances of them spreading the disease to healthy plants are also reduced.

Eradication Of The Disease Source Through Cultural Or Chemical Sanitation

Complete eradication is practically impossible to accomplish. However, susceptible crop plants and nonsusceptible crops often may be rotated in a way that eliminates the population of the disease organism in a field site. Crop rotation is only partially effective against soil-inhabiting organisms that are capable of surviving in the soil for several years.

Removal and destruction of diseased parts or entire plants can prevent the spread of disease in an established commercial planting, and it is also an effective procedure in the production of disease-free planting stock. The purpose of plant removal is to destroy a source from which a disease organism might spread to healthy plants in the same or other plantings.

Eradicating the alternate hosts of certain rust disease organisms has long been used to break their life cycle.

Disease organisms can be destroyed in stored plant parts by heat, fumigation, and other chemical applications. Treatment to reduce or inactivate disease organisms in the soil may also be used. Soil may be treated with chemicals, heat, or by flooding or fallowing.

Most fumigant-chemical treatments reduce or eliminate all organisms in the soil - good as well as harmful. Treatments such as these should be used only in the absence of crop plants. Because disease organisms must be largely eliminated from the crop's root zone, a large amount of soil must be treated. Compared with insect and weed control pesticides, a massive quantity of chemical is required.

Heat treatment of soil is highly satisfactory to use with small quantities of soil in greenhouse benches, mushroom houses, and beds or in limited ground-bed operations.

Plant Protection

Plants may be protected from disease organisms by chemical applications or through adjustments in cultural practices.

Most spraying, dusting, and seed treatments put a toxic chemical barrier between the plant and the inoculum in order to prevent infection. In this sense, chemicals are protectants.

Improving air circulation in greenhouses to reduce humidity at the leaf surface is an example of modifying the environment in order to protect the plant from infection.

To prevent storage diseases, favorable environmental conditions must be maintained to ensure normal wound-healing of the product being stored (e.g., fruits and vegetables), but conditions must not favor rapid development of disease organisms.

Humidity should be high enough to prevent excessive drying and to facilitate wound-healing but low enough to avoid heavy fungus growth. Storage of each crop must be considered as a separate problem, and the environmental conditions required for curing and the maintenance of quality must be weighed against the environmental conditions that favor disease.

Development Of Resistant Crops

Resistant varieties may be selected or developed by proper selection, breeding for resistance, or obtaining resistance through plant nutrition.

Physiological resistance is usually based on an inhibitory substance in the tissues of the crop plant or on some form of chemical incompatibility of crop disease organism. Mechanical resistance may include an unusually thick cuticle or cork layer or other physical characteristics that make it difficult for organisms to come into direct contact with or penetrate the plant tissues. Functional resistance includes such reactions as the closing of leaf pores when conditions are favorable for infection.

Acquired immunity comparable to that induced in humans and animals by vaccination or inoculation with serum has not yet been used successfully with plants.

Control Through The Use Of Chemicals

One of the most effective means of plant disease control is the use of natural or synthetic chemicals. Chemical control is often the only feasible means of attacking a disease problem. It may at times be more economical and effective than other measures. Many diseases cannot be controlled by any other means, and adequate quality and yield of crops require disease control through the use of chemicals.

Chemicals may act either to keep out the disease organism (exclusion by seed treatment); to remove, or eliminate the disease organism at the source (eradication); to prevent plant infection (protection); or to cure plants (therapy). The majority of chemical control measures involve the principle of protection - preventing the disease organism from entering the plant and starting an infection. To accomplish this, chemicals may be used to inactivate the organism at the site of infection.

In addition to the use of fungicides, chemical control of disease may be achieved with nematicides, insecticides, herbicides, or bacteriacides. In addition to providing direct control of pathogenic nematodes, nematicides may control nematode carriers of disease organisms or kill nematodes that provide infection sites for fungi and bacteria. Insecticides similarly control insect carriers of disease organisms, such as the leafhoppers and aphids that transmit viruses.

Herbicides may be used to prevent the production of disease organisms by eliminating the alternate host of the organism. Herbicides may also be used to kill weeds that may serve as alternative hosts. Certain virus diseases are particularly amenable to this means of control.

Many chemicals are toxic to various life forms. This is an essential feature of chemical control. Chemicals must be less toxic to the crop plant than they are to the organism they are designed to control. A protective fungicide should kill fungi without significant damage to the crop plant.

Chemical treatment of plants may be used to prevent the reproduction of disease organisms. Treatment of apple leaves protects leaves from new scab infections and prevents spore production in existing infection centers on the leaves.

Herbicides can chemically prevent the production of inoculum. This treatment is feasible when one series of plants is of little or no value relative to the crop plant. The destruction of barberry as a source of stem rust of wheat is an example; however, this destruction is only partially effective as a control measure. Spores, produced on wheat, are wind-borne at high altitudes and may be deposited hundreds of miles from where they were produced. The same principle of destroying a plant of low value applies to other organisms with alternate hosts.

An example of inactivation of a potential inoculum source is the destruction of cull potatoes that may harbor the late-blight fungus, or herbicide spraying cull piles to prevent sprouting and subsequent disease development. Here the source of the fungus is available, evident, and small. By contrast, prevention of early season spore formation and release by the apple scab fungus by treating the orchard floor with fungicides is relatively ineffective and not widely practiced. Not only is the source widespread and abundant, but also only the spores in the upper layer of leaves are exposed to the fungicides, and all of the sources are not evident. Again, it is the amount of inoculum that survives that is important.

Many plant parts (e.g., seeds, bulbs, tubers, fruits, and stolons) carry organisms that can cause storage rots and many other types of disease. These diseases can be controlled if the source can be eliminated or reduced to levels insufficient to cause disease. Treatment with chemicals, gaseous fumigation of plant materials, and storage space, along with adjustment of environmental factors may be used to eradicate or exclude disease sources.

The principle of seed treatment is primarily control of sources of disease, although chemical seed treatment may also protect against infection from organisms in the soil. Fungicides are used as seed protectants to coat the seed and provide protection against damping off and seed-rotting organisms in the soil.

To be effective in providing protection of susceptible (foliage), fungicides and bactericides must be on the plant before the organisms arrive. Fungicides may prevent spore germination, cause abnormal germination so that infection fails, or delay the germination process sufficiently so that drops of water on leaf surfaces dry before the germ tubes of germinating spores penetrate the plant. The time required for the organism to enter the host may be short, sometimes only an hour or two.

To prevent penetration and infection, an effective dosage of a fungicide must be applied. In contrast to insects, which move over the plant before they feed or during feeding, units of fungus inoculum do not migrate freely after they are deposited, even when spores are motile. Fungicidal deposits that are evenly distributed over the host surface are more effective than unevenly distributed deposits.

Protection of foliage by fungicides is usually made only by repeated applications.

In-row or spot applications of soil fungicides at planting time may protect the young seedling from many types of soil organisms. In this case, the chemical inactivates the inoculum and prevents it from invading susceptible young crop plants.

Soil fungicides may also be used to protect the roots of established plants from invasion by disease organisms. These materials, applied as drenches, must penetrate the root zone in an effective concentration in order to inhibit fungi or nematodes.

Chemotherapy With Systemic Fungicides

Chemotherapy is the control of disease through the use of chemicals that exert their action within the plant. Such chemicals and techniques cure or treat new or established infections.

These chemicals may act by inactivating toxins produced by the disease organism; or by a direct fungitoxic or fungistatic effect on the disease organism. Indirect approaches to chemotherapy involve chemically increasing the resistance of the plant or otherwise changing the chemistry of the plant so that it is no longer a suitable target.

WEED CONTROL AND HERBICIDES

Any plant can be considered a weed if it grows where you don't want it to grow. Some crop plants may be considered weeds. Volunteer small grain, after harvest in the late summer, may be a severe problem if the field has been seeded to a legume or grass forage. One of the worst weeds in soybeans - when soybeans follow corn in the rotation - is volunteer corn.

Pigweed, lambsquarters, yellow foxtail, giant foxtail, and barnyard-grass are common weeds. In different areas of the country they may have different names; therefore, almost all plants - common or uncommon - have now been categorized in a plant classification system and given a scientific name to identify them anywhere in the world.

From this classification, weeds can be identified and herbicides selected and used, if necessary, for proper control.

Types of Weeds

Weeds may be classified into four major groups - summer annuals, winter annuals, biennials, and perennials - which simplifies understanding the weed control program for each group. The difficulty in controlling weeds is understanding the control program for each weed or group of weeds.

1. Summer annual weeds grow every spring or summer from seed; they produce seed, mature, and die in one growing season.

Seed from most summer annual weeds germinate during a two-month period during the spring (May and June in Pennsylvania). Then the seed lies dormant until the next spring. There are usually a few seeds of every species that germinate during summer or fall but seldom in numbers equal to the spring flush. Of the millions of weed seed lying beneath every square foot of land, probably not more than 5 percent will germinate in any growing season. Summer annual weeds are the greatest problem in spring when annual crops are planted and new seedlings of perennial crops are made because seed germinates most readily in disturbed soil.

One of the simplest methods of solving a weed problem is to avoid it. Mid-summer legume and grass seedlings and normal fall seedlings of winter wheat or barley are seldom bothered with summer annual weeds. A second solution is to plant the crop in early spring before most of the weed seed germinates, a practice successful with normal plantings of spring oats.

A crop rotation of perennial crops, such as legumes and legume-grass mixtures where the soil is not tilled in the spring, greatly reduces the

numbers of summer annual weed seed that germinate. Since these areas are usually grazed or cut for hay, weeds that do germinate do not go to seed. For that portion of the rotation - when small grains or forages are planted - most summer annual weeds are controlled naturally by unfavorable conditions for germination in the spring and by good crop competition at the time summer annual weed seed would normally germinate.

Certain annual crops such as corn, soybeans, and sorghum must be planted after the soil is warm; however, since the life cycles of these crops are synchronized with the weeds, there is a weed problem and a great need for herbicides. Some weeds can be controlled by picking the right hybrids, using good fertility, and planting a good population at the right time. For those weeds which cannot be controlled by normal cultural practices, use herbicides.

Summer annual weeds are easily controlled by "pre-emergence" herbicides. These herbicides are applied before the weeds and crops (corn, soybeans) emerge. Depending on how the herbicide works, the weed seedling is killed before or soon after it emerges. None of the herbicides used for weed control on cropland will kill dormant weed seed except methyl bromide.

If weeds are not controlled in the seedling stage, they can usually be controlled with "post-emergence" herbicides which are applied after the weeds and most crops have emerged. The larger the annual weeds, the more difficult they are to control. Therefore, you may need more herbicide or a "hotter" herbicide for effective control with a greater chance of injuring the crop. Therefore, post-emergence treatments should be used in emergencies where previous efforts to control the weeds have failed. Some herbicides that are absorbed only through the foliage can only be applied after the weeds have emerged but these must be matched to the crop in order to prevent crop injury. Although the herbicide may be selective for the crop and give total control of emerged weeds, competition during the first 2 or 3 weeks of crop growth may be enough to reduce crop yields.

Spraying summer annual weeds about a month before frost is unnecessary, since ripe seed will probably already have been produced and the remaining vegetation will usually be killed by the first killing frost.

2. Winter annual weeds come up in late summer or fall from seed and mature and produce seed the following spring or summer.

Seed from most winter annual weeds are dormant in the spring but germinate in the late summer or fall. Some species, such as common chickweed, can germinate under snow cover. These weeds start growth at the first sign of spring and many species bloom and produce ripe seed by mid-May or June. This means that some weeds can reseed themselves before land is prepared for late planted crops, such as soybeans or sorghum. The growth cycle of winter annuals is also synchronized with fall-sown small grains, such as winter wheat or barley. There are several species, such

as field pepperweed, which are so closely synchronized that the weed produces ripe seed at the same time that the grain ripens and the weed seed is thrashed along with the grain. Unless the grain is cleaned, the weed seed is fed to cattle and spread back on the field in the form of manure. Weed seed in grain used for seed is seeded along with the grain to give an immediate weed problem.

Competition from the crop should be the first weed-control weapon. Use a seeding rate which gives a good stand and fertilize to obtain maximum yields which should also supply maximum competition. Those weeds not controlled by good management practices have to be controlled by herbicides.

3. Biennial weeds grow from seed anytime during one growing season. They normally produce a rosette of leaves close to the soil surface the first year; then flower, mature, and die the following growing season.

Biennial weeds, though relatively few, may become established from seeds anytime during the growing season. Wild carrot and bull thistle are two of the most common biennial weeds. A true biennial never produces flowers or seeds the first year but forms a rosette of leaves that usually lie close to the ground. Such weeds are well adapted to lawns, pastures, hay fields, and orchards where grazing or mowing removes very few of the rosette leaves. Consequently, growth and energy storage in the roots or crown continues until a killing frost. This large amount of stored energy supports spring growth, ahead of other pasture and forage species. If biennial weeds are not controlled before this time, there are no forage species that will out compete them. Unless the flower stalks are mowed off or plowed under, they will flower and produce seed. The plant dies after the seed matures.

The best time to control biennial, as well as all weeds, is in the seedling stage. This is the only time that the crop can compete with and possibly control weeds. Once established, the biennial weeds can only be controlled by herbicides. Soil-applied herbicides are ineffective because these herbicides leach only deep enough to contact a small portion of the weed's large and deep root system. As a result, not enough herbicide is absorbed to kill the weed. Foliar-applied herbicides, such as 2,4-D, which are absorbed through the foliage and translocated within the plant to the root system, kill the whole plant. However, since these herbicides are effective on most broadleaved species and are selective for grassy species, they often cannot be used where you may want to save certain broadleaf species. They can be used very effectively on pure grass areas such as lawns, orchards, and some pastures.

4. Perennial weeds become established by seed or by vegetative parts, such as root stocks or rhizomes; once established, they live for more than two years.

Since perennial weeds live indefinitely, their persistence and spread is not as dependent upon seed as with the other three weed groups. Seed is the primary method of introducing these weeds into new areas; however, perennial weeds are often spread during soil preparation and cultivation. Most perennial weeds that spread by rhizomes or root stocks will spread in circular patches if left, undisturbed. In cropped fields, patches of nutsedge, and Johnsongrass spread in oblong patches in the direction the field is worked.

Perennial weeds grown from seed are no more difficult to control than any other kind of weed coming from seed, but once established, perennial weeds are the most difficult to control. They compete with any crop, especially row crops where competition between rows is not too great. Perennial weeds also get an early start in the spring and compete with perennial crops, such as alfalfa and other forage species.

Although perennial weeds are difficult to control, they are more easily controlled at certain times of the year.

One of the best times to control perennial weeds is in late summer or early fall before they have a chance to build up large energy reserves prior to winter. Perennial weeds store energy (starch) in underground roots, stems, bulbs, and crowns during summer and fall. If these weeds are prevented from storing energy, they may not survive the winter.

To reduce weed vigor, remove top growth by heavy grazing, mowing, or by using photosynthetic-inhibiting herbicides such as diuron or atrazine. If the weed's leaves and stems are removed, no sugar and starch can be produced through photosynthesis, thus there is no buildup of energy. This is seldom sufficient to effectively control a perennial weed but it can be a good first step in weakening it so that a future treatment works better. Photosynthetic-inhibiting herbicides prevent the weed from using sunlight, although the leaves and stems may be left on the plant. The herbicide must be applied in early fall before reserve energy storage begins but not so early that the herbicide will dissipate and become inactive before frost. For most of the commonly used photosynthetic-inhibiting herbicides, such as atrazine or simazine, the active period is about 6 to 8 weeks. This is approximately the length of time, prior to a killing frost, they may be applied. Timing is critical because the weed should never have a chance to recover from the herbicide treatment. Grazing or mowing should also be continued until frost to prevent the weed from recovering from continued defoliation.

The next best time to attack perennial weeds is in the spring. Perennial weeds are weakened by winter because part of the reserve energy is used for respiration to keep the weed alive. If a fall treatment is used, some of the weaker perennial weeds may die (winterkill) and the stronger plants be greatly weakened. Grazing or mowing can be used to defoliate these weeds again in the spring but this should be delayed until there is 8 to 12 inches of new growth.

The initial growth in the spring uses reserve energy from underground roots, stems, bulbs, and crowns which further weakens these weeds. Growth should not be allowed to continue much beyond a foot since it will start replacing some of these energy reserves, making the weed more resistant to control the longer it is allowed to grow. If a crop such as corn is planted, this would be the ideal time to plow and turn under all of the new growth so the weeds will have to use reserve energy to produce new stems and leaves. In the case of no-tillage corn where the land is unplowed, a contact herbicide, such as paraquat, may be used to "burn" off all of the topgrowth so that the weed has to start over again. Since paraquat leaves no effective residue, it is normally used with photosynthetic-inhibiting herbicides such as atrazine, simazine, or a combination of the two which inhibits photosynthesis in the regrowth and further weakens the weed. A crop compatible with the herbicides you have used should be planted to provide competition and shading during the growing season. Some perennial weeds are so vigorous that it takes a series of treatments for effective control. Make maximum use of nonchemical means to weaken weeds first, so that when the herbicide is used it gives the best control possible.

Most broadleaved perennial weeds can be most effectively controlled without photosynthetic-inhibiting herbicides which are primarily root absorbed. In general, broadleaved perennial weeds have a deep root system so that only the portion of the root system in the top 4 to 6 inches of soil can absorb a soil-applied herbicide. Since this may be less than 5 percent of the total root system, insufficient herbicide is absorbed. Therefore, foliar-applied herbicides, such as 2,4-D or dicamba, work much better on perennial weeds such as cypresswood and horsenettle. The best time to apply these herbicides is well before maturity or in the spring after there is sufficient growth to weaken the weed and sufficient foliage to intercept and absorb as much of the applied herbicide as possible.

Herbicide Action

Herbicides are grouped according to the pathway by which they enter the weed and the result that is obtained.

1. Foliage - Nonselective - Contact. Herbicides applied to the weed's foliage, in the absence of a crop or directed underneath a crop, kills the foliage the herbicide contacts with little or no translocation to underground or shaded parts of the weed. Since biennial and perennial weeds normally have dormant and protected buds with stored energy in the crown or root systems that produce new growth, these weeds will recover after treatment. Small annual weeds are completely and permanently controlled. For example, paraquat, applied before a no-tillage corn planting, or used as a directed spray underneath fruit trees, will control seedling weeds. Since contact herbicides normally don't leave any residue beyond the

initial contact, a residual herbicide is commonly mixed with the contact herbicide to control the regrowth of the biennial and perennial weeds plus weeds coming from seed.

2. Foliage - Selective - Contact. These herbicides kill weeds by a contact-burning effect on the foliage. Due to differences in the waxy covering on the leaves, certain crops and weeds are not injured. These herbicides are effective only on weeds in the seedling stage and biennial and perennial weeds with dormant buds near the soil level will regrow after the foliage is killed. Generally, these herbicides are not translocated, although, some may have a short residual effect in the soil. For example, dinitro is used to control broadleaf annual weeds in soybeans, new legume and seedlings.
3. Foliage - Nonselective - Translocated. These herbicides are applied to the foliage of the weeds and are absorbed and translocated throughout the plant. Since they are nonselective, they cannot be applied when a crop is present but they can be used before planting or after harvesting. For example, Amitrol T which can be used on noncrop land only is nonselective and will kill anything that is growing. Amitrol T has only a short residue so dormant weeds or weeds germinating from seed after herbicide application will not be controlled. A residual herbicide, such as atrazine or simazine, is commonly mixed with this herbicide to give continued weed control for the rest of the year.
4. Foliage - Selective - Translocated. This group includes some of the oldest and most widely used herbicides. These herbicides are applied to the foliage and are absorbed primarily through the foliage and translocated throughout the plant. They are also selective, so weeds may be treated while the crop is present with little or no injury to the crop. The best example of this type of herbicide is 2,4-D. For example, 2,4-D has many uses; it takes dandelions out of lawns or broadleaved weeds out of oats, wheat, barley, and corn. Dicamba is used for tough-to-control weeds such as thistle, common milkweed, and horsenettle. Other common herbicides in this group are 2,4,5-T, and 2,4,5-TP. These herbicides are used for brush control along highways, railroad right-of-ways, fence lines, and in waste areas. They will selectively remove brush without killing grass so that there are no bare areas once the brush dies.
5. Soil - Nonselective - Short residual. Only a few herbicides belong to this group. The most common, methyl bromide, is a gas at normal air temperature and dissipates into the air if the area to be treated is not covered. A sheet of plastic or gas-tight cover must be used and the gas is released under the cover. All weeds, including weed seed, are killed by methyl bromide. The cover must be kept on the treated area for about 24 hours for best results; another 24 hours is required to aerate the soil after the cover is removed. After this 48-hour period, anything can be planted without injury, making methyl bromide one of the shortest residual herbicides available.

6. Soil - Selective - Short residual. Any herbicide that is applied to the soil prior to planting a crop or immediately after planting and has a residue of less than one year belongs to this group. This includes almost all those herbicides used for weed control in vegetable and feed crops as well as for other specialized crops such as flowers and ornamentals. Since the crop is present at the time the herbicide is applied or it is planted soon after application, the herbicide must be selective and should not cause injury to the crop. These herbicides are often referred to as pre-plant incorporated or preemergence-type herbicides. For example, Treflan on cotton, Lasso on corn, linuron on soybeans, or EPTC on ornamentals have residues that last from 6 to 8 weeks to all summer. Because these herbicides are applied to the soil, they are primarily root absorbed although some may be absorbed through the foliage if any is present at the time of application.
7. Soil - Nonselective - Long residual. Herbicides that are used to control all vegetation for as long as possible are desirable for use near parking lots, around buildings, oil storage areas, factory supply storage areas, etc. For example, bromacil and simazine, at high rates of 10 to 25 lbs. per acre, last for 3 to 5 years. Bromacil will kill brush and trees present in a treated area. Simazine will not kill deep rooted trees since it doesn't leach as readily as bromacil.
8. Soil - Selective - Long residual. These herbicides can be used only on deep rooted crops, such as fruit trees, nut trees, cane fruits, and grapes. They may be applied to the foliage of the weeds, although most of the herbicide is eventually absorbed through the root system. These herbicides have a low solubility in water and do not leach readily; therefore, they seldom get down to the root systems of the deeper rooted crop. They have a residue and will give weed control for more than one year. For example, simazine applied at rates of about 5 pounds per acre will control shallow rooted weeds without injuring deeper rooted crops. At higher rates, selectivity is lost and it becomes a nonselective herbicide.

Herbicide Use

A perfect herbicide does not exist. No herbicide has the capability of controlling all weeds without injuring the crop. Since every herbicide has advantages and disadvantages, the choice of a herbicide is important.

Consider these points when you choose a herbicide:

1. Is it registered for use on the crop you want to treat? If it is, the directions for use and rate of application will appear on the label.
2. Can it be used at the stage of growth at which the crop now exists? Very few herbicides can be applied anytime during the growth cycle of a crop. One of the best examples of how stage of growth affects herbicide

performance is with alachlor (Lasso). It is one of the best herbicides for annual grass control if it is applied before the grass emerges; however, it is useless if applied after the grass has emerged.

3. Will it control the weeds that are giving you the most problem? Many weed control measures fail because the herbicide can't control the weeds present.
4. Will the herbicides leave a residue that might affect the crop you want to plant next in rotation? Certain herbicides classified as long residual herbicides can injure or kill sensitive crops.

For more information contact your county Extension agent or a commercial pesticide applicator.

PERSISTENCE OF HERBICIDES IN SOIL

The soil persistence of a herbicide is the length of time it remains active in the soil, that is, its active life. Farmers must consider persistence in using both preemergence and soil sterilant herbicides. Since preemergence herbicides are used to a greater extent than soil sterilants, our discussion here will be limited to preemergence herbicides.

Long persistence is desirable when it allows season-long weed control. However, when it extends past the growing season, it leaves a carryover or residual toxicity that may damage succeeding susceptible crops. Persistence, therefore, involves not only length of weed control, but also the possibility of soil residues.

It is sometimes desirable to have long persistence, especially in crops planted early in wide rows. The crop then does not grow so high or shade the weeds so fast as it ordinarily would. A longer period of weed control is therefore essential. The rows are shaded more rapidly in narrow-row culture than in wide-row culture. In narrow-row culture, so long as the initial control is adequate, the herbicide rate may possibly be reduced, since long persistence is not needed.

Anything that affects the rate of disappearance or loss of activity of a herbicide will affect its persistence. Soil, climatic, and herbicidal properties all have such an effect.

The soil factors may be divided into three categories--physical, chemical, and microbial. The physical conditions are soil composition (sand, silt, clay, and organic matter content), moisture-air relationships, and soil temperature. The chemical properties are pH, cation exchange capacity, and kind of clay. The microbial properties are the kind and amount of microorganisms plus the microbial environment, which consists of nutrients, temperature, and moisture. The climatic variables are primarily moisture, air temperature, and sunlight. The properties of the herbicide that affect its persistence are water solubility, vapor pressure, and susceptibility to chemical or microbial alteration or degradation.

Because the application rate and uniformity of distribution affect the concentration of the herbicide at a given place, accurate calibration and even distribution are essential. You must know how much to apply and how much you do apply.

The processes that are involved in decreasing the persistence of a herbicide are (1) volatility, (2) photodecomposition, (3) adsorption, (4) leaching, (5) plant uptake, (6) microbial decomposition, and (7) chemical decomposition.

Volatility is the process whereby the herbicide changes from a solid or liquid to a gas. It is associated with the vapor pressure of the chemical

and increase with temperature. Photodecomposition is the breakdown of the herbicide by sunlight; thus the extent of exposure to sunlight is the primary variable. If a herbicide is subject to appreciable losses by either or both of these processes, then incorporation may help to reduce the loss. Such chemicals as Eptam and Vernam are incorporated because of their volatility.

Adsorption is the process whereby the herbicide is bound to the surface of a soil clay or organic matter particle. The strength and extent of the binding and the ease with which the material is replaced or released will affect the rate needed to control weeds and also its persistence in a given soil. Soils vary greatly in their adsorptive capacity, depending on the kind and amount of clay and organic matter. Herbicides that are adsorbed to a large extent are Atrazine, Lorox, and Treflan; thus their rate of application must be adjusted to conform with the soil type.

Leaching occurs when a herbicide is dissolved in water and moves down through the soil profile. The primary factors involved in leaching are the amount of available water, the soil texture, the water solubility of the herbicide, and the degree of adsorption of the herbicide. A small amount of leaching is desirable to move the herbicide from the soil surface into the top one or two inches of soil, where most weed seeds germinate. If the herbicide leaches past the area of germinating weed seeds into the area of germinating crop seeds, then the crop may be injured if its tolerance is not adequate. On the other hand, herbicides that have low water solubility and that are strongly adsorbed may never reach the desired zone without adequate rainfall or incorporation.

Plant Uptake, that is, adsorption of the herbicide by the plant roots, reduces the concentration of the herbicide in the soil. The persistence may be less if the herbicide is broken down (metabolized) by the plant or if the top growth is harvested and removed from the field. Thus, for example, if Atrazine is applied at the same rate in a heavy quackgrass infestation as in a light infestation, the persistence will be less in the heavy infestation.

Microbial decomposition occurs when the soil microorganisms utilize the herbicide as a source of food or energy. Herbicides vary greatly in their susceptibility to microbial decomposition. If the right kind and number of microorganisms are present and if soil conditions are favorable for the microorganisms, then a herbicide may be rapidly decomposed in the soil. Thus, for example, 2,4-D lasts only a short time in the soil, while Atrazine degradation is quite slow.

Chemical decomposition occurs as hydrolysis, oxidation, reduction, and other chemical reactions. Many soil chemical and physical conditions, such as moisture, aeration, pH, temperature, and organic matter content, regulate the rate of chemical and microbial decomposition.

Since many factors and processes are involved in the persistence of a preemergence herbicide, it is impossible to give the exact length of persistence for a particular herbicide. Only an approximate time can be estimated for a given set of conditions.

POTENTIAL PHYTOTOXICITY

Phytotoxicity, or pesticide damage to plants, results in such things as abnormal growth, leaf drop, and discolored, curled, and spotted leaves. If phytotoxicity is severe, the plant may die. Phytotoxicity often mimics such things as insect damage, plant disease, and response to poor growing conditions such as insufficient moisture, improper fertilization, etc. The following items are especially relevant to the phytotoxicity problem:

1. A wide variety of plant material
2. Pesticide drift
3. Pesticide persistence beyond the intended period of pest control.

Wide Variety of Plant Material

Ornamental plants vary from herbaceous to semi-woody and distinctly woody species. Generally, herbaceous plants (chrysanthemums, petunias, turfgrasses, etc.) are more susceptible to pesticide damage than woody ones. Even the woody plants are more susceptible when growth is young and tender. Greenhouses present a special problem as phytotoxic vapors tend to be trapped in the closed environment.

Plant damage is more likely to occur with herbicides. Fungicides except those applied as smokes tend to be less hazardous to plants than herbicides and insecticides. The pesticide label is the best guide to the safe use of pesticides on a specific ornamental plant. If the pesticide is not known to be safe for use on a specific ornamental plant, it should not be used. Where different plants are rotated in the same soil, a pesticide used to control some pests on one plant may leave residues in the soil that will damage or kill another plant. This is especially true of some herbicides.

Warm season turfgrasses include the bermudagrasses, zoysiagrasses, St. Augustinegrass, and centipedegrass as well as some varieties which have been developed from these species. Cool season species include such plants as the bluegrasses and fescues. Some herbicides used to control weeds in warm season grasses will damage or destroy cool season grasses. The pesticide label is the best guide as to whether the pesticide should be used on a specific turf species.

Drift Problems

The proximity of different plants with varying susceptibility to pesticide damage requires that commercial pesticide applicators in the ornamental and turf category be especially aware of drift problems. There are several steps that can be taken to prevent damage to non-target plants.

Drift can be prevented or minimized by using methods described in a later section. Pesticides should be selected that are safe for both target and non-target plants if possible. It may be necessary to place a barrier around the target plant or remove susceptible plants from the area (such as removing susceptible potted plants from a greenhouse). Finally, you may decide not to apply a pesticide to the target plant because the benefit does not justify the hazard to near-by plants.

Persistence Beyond the Intended Period of Control

The period of pesticide residual activity varies greatly from one class of pesticides to another. Persistence is directly related to rate of application, soil type or texture, temperature, moisture conditions, rainfall amounts, and other factors. Commercial applicators must be familiar with persistence of each pesticide which may be applied to ornamentals and turf, especially where adjacent areas may be affected, treated soil is used to grow other plants, or where humans and pets frequent the area. An example of persistence causing a problem in plant handling would be the use of a highly toxic systemic insecticide on plants just before they are sold to the public. It is very possible that in the process of selecting a plant, the soil would be handled and the general public would be exposed to the active chemical. In situations such as this, it is necessary to hold the plants until the chemical has lost its toxicity. This information can be found on the label.

Persistence is an important part of pest control, since successful pest control requires a knowledge of the persistence period to make subsequent applications. For example, generally herbicides used for preemergence weed control in turf persist for 60 to 90 days; and postemergence herbicides last from one or two days to three or four weeks, depending upon the specific herbicide involved.

Persistence can be an advantage to the applicator for long term control of the pest. The use of a chemical to control Pythium (cottony blight) on turf or root rot on chrysanthemums is a situation in which pesticide persistence is desired. However, problems can develop when applications are made too frequently which raises the level of the chemical in the soil to potentially phytotoxic amounts.

CALIBRATION OF PESTICIDE APPLICATORS

Proper calibration of pesticide applicators is essential for safe, economical and effective pest control. All machines should be calibrated before initial use and periodically during operation. There are many factors which cause variation in rate and efficiency of application.

This lesson plan will deal with calibration of ground machines.

Calibration of Sprayers

The amount of material applied is usually measured in "gallons per acre."

Sprayer speed is measured in "miles per hour" or "feet per minute."

Nozzle spacing is measured in inches. Pressure at the nozzle is measured in pounds per square inch "psi."

Orifice size is a factor in sprayer output. The proper nozzle is selected by number from manufacturer's catalogs. They are rated in "gallons per minute" at a designated pressure.

Determining Sprayer Speed

Speed can be calculated in several ways.

88 feet per minute = 1 mile per hour. The sprayer can be timed while traveling in the field for 1 minute. Measure this distance in feet. Divide by 88 to obtain miles per hour.

Distance Traveled in One Minute = M.P.H.

The chart most commonly used in Mississippi to determine speed requires measuring 300 feet and timing the sprayer over this distance. Speed in "miles per hour" can then be read directly from the chart.

One method of calibrating is the "seconds per quart" method. A chart is developed whereby when speed and gallons per acre desired are known, the seconds to catch 1 quart from 1 nozzle or all nozzles for 1 row can be read directly. The following formula is used to develop the chart and is handy to use in calibrating a sprayer.

Seconds to catch 1 quart =

$$\frac{89,100}{(\text{nozzle spacing in inches}) \times (\text{miles per hour}) \times (\text{gallons per acre})}$$

89,100 = a constant

Nozzle spacing in inches

If you catch the material from 1 row's nozzles then the row width in inches can be substituted in the formula for "nozzle spacing in inches."

If spray material is to be caught from 1 nozzle, the actual spacing on a boom is used.

In the case of a post emergence applicator with 4 nozzles per row, the nozzle spacing would be row width in inches divided by the number of nozzles per row.

$$\text{Nozzle spacing in inches} = \frac{\text{row width inches}}{\text{number of nozzles per row}}$$

Problem - a tractor sprayer is timed for one minute. The distance measured is 440 feet.

Ten gallons per acre will be applied with a broadcast boom - nozzles spaces 20" apart.

$$\text{Solution} - \frac{400 \text{ feet}}{88} = 5 \text{ miles per hour}$$

Seconds per quart from one nozzle =

$$\frac{89,000}{(20" \text{ nozzle spacing}) \times (5 \text{ miles per hour}) \times (10 \text{ gallons per acre})}$$

$$\frac{89,100}{20 \times 5 \times 10} = \frac{89,100}{1,000} = 89 \text{ seconds}$$

Sprayer should be parked and pressure adjusted to where 1 quart of material will be caught from 1 nozzle in 89 seconds.

This same procedure can be used to calibrate any low gallonage sprayer for broadcast or directed spray application.

CALIBRATION TABLE - Commonly used in application of herbicides to row crops.

Speed		Gallons per acre (13,068 row feet) from 1 row nozzles									
MPH	Seconds per 300 ft.	6	7	8	9	10	12	14	16	18	20
2.6	79	143	122	107	95	86	71	61	54	48	43
2.8	73	133	114	99	88	80	66	57	50	44	40
3.0	68	124	106	93	83	74	62	53	46	41	37
3.2	64	116	99	87	77	70	58	50	44	39	35
3.4	60	109	94	82	73	66	55	47	41	36	33
3.6	57	103	88	77	69	62	52	44	39	34	31
3.8	54	98	84	73	65	59	49	42	37	33	29
4.0	51	93	80	70	62	56	46	40	35	31	28
4.2	49	88	76	66	59	53	44	38	33	29	26
4.4	46	84	72	63	56	51	42	36	32	28	25
4.6	44	81	69	60	54	48	40	35	30	27	24
4.8	43	77	66	58	52	46	39	33	29	26	23
5.0	41	74	64	56	50	45	37	32	28	25	22
5.2	39	71	61	53	48	43	36	31	27	24	21
5.4	38	69	59	52	46	41	34	30	26	23	21
5.6	37	66	57	50	44	40	33	28	25	22	20
5.8	35	64	55	48	43	38	32	27	24	21	19
6.0	34	62	53	46	41	37	31	26	23	21	18
7.0	29	53	46	40	35	32	26	23	20	17	16
8.0	25	46	40	35	31	28	23	20	17	16	14
9.0	23	41	35	31	28	25	21	18	15	14	13
10.0	20	37	32	28	25	22	19	16	14	12	11

Procedure for Determining Gallons Per Acre Being Applied

1. For 38" rows measure off 564 feet. If rows are 40" measure off 544 and put a stake at starting point and ending point.
2. Start tractor far enough away from starting mark, so that it will be at selected speed in the gear selected for spraying when starting mark is reached.
3. Time tractor from starting mark to end mark of course previously marked off. This time should be re-checked for accuracy.
4. Park tractor. Set pressure gauge at desired pressure while engine is being run at same throttle setting. Turn on sprayer and catch spray from one row's nozzles for exact length of time it took to cover measured distance one way. For each pint of spray caught you will be applying 3 gallons of mixture per acre. Pressure can be adjusted to apply desired amount. It is suggested that a large container be used to catch material, and material then poured into pint jars for accurate measurement.

Use the table below to determine amount being applied.

Ounces Caught	Gallons per Acre	Pints Caught	Gallons per Acre	Pints Caught	Gallons per Acre
1	.1875	3	9	8 1/3	25
2	.375	3 1/3	10	8 2/3	26
3	.5625	3 2/3	11	9	27
4	.75	4	12	9 1/3	28
5	.9375	4 1/3	13	9 2/3	29
6	1.125	4 2/3	14	10	30
7	1.3125	5	15	10 1/3	31
8	1.5	5 1/3	16	10 2/3	32
9	1.6875	5 2/3	17	11	33
10	1.875	6	18	11 1/3	34
11	2.0625	6 1/3	19	11 2/3	35
12	2.25	6 2/3	20	12	36
13	2.4375	7	21	12 1/3	37
14	2.625	7 1/3	22	12 2/3	38
15	2.8125	7 2/3	23	13	39
16	3	8	24	13 1/3	40

Calibrating Granular Applicator

Although granular materials are not as widely used as liquid, the importance of calibration is not lessened.

Several factors can cause a variation in the application rate including the following:

1. Area of the metering orifices.
2. Speed of the agitator.
3. Ground speed of the applicator.
4. Nature and size of the granules.
5. Roughness of the field.
6. Humidity.
7. Temperature.

A different applicator setting may be necessary with each chemical applied because there is wide variation in the size and density of the particles. The nature of the inert carrier will also affect application rate.

With new granular applicator, there is usually a printed calibration procedure. This will be quite adequate. The need often arises to calibrate an applicator and no instruction sheet is available. Some procedure must then be worked out to determine the amount of material applied to a given area.

Unlike a liquid, granules must be weighed or poured into a jar with graduations made in ounces marked for a particular granule. A set of scales can be used to weigh a pound. This amount can be poured into a jar. Sixteen increments can be marked to represent ounces.

The following steps can be taken:

1. Fasten paper or plastic bags over outlets of applicator.
2. Determine pounds per acre needed.
3. Determine distance for tractor to travel to represent a predetermined fraction of an acre.
4. Calculate ounces of granules to apply to this fraction of an acre.
5. By trial and error set applicator to apply desired amount.
6. For accuracy, check each row.

Example:

1. .5 pounds of active ingredient needed per acre.
2. Material contains 5% active ingredients.
3. $\frac{.5 \text{ pounds}}{.05} = 10 \text{ pounds needed per acre.}$
4. Row width is 40" or $3 \frac{1}{3}$ ft.
 $43,560 \div 3 \frac{1}{3} = 13068 \text{ ft. in an acre.}$
5. $13068 \div 10 = 1306.8 \text{ row feet required for 1 pound.}$
6. We can reduce this to $\frac{1}{4}$ lb. or 4 oz. by dividing 1306.8 by 4.

$$\frac{1306.8}{4} = 326.7 \text{ ft.}$$

7. By trial and error adjust applicator to apply 4 oz. in 326.7 ft.

If a specified distance to measure is desired, the formula below can be used.

$$\frac{\text{Rate of total material per acre}}{\text{Row length in 1 acre}} = \frac{X}{(\text{measured distance})}$$

X = weight of material to be caught.

Conversion Factors and Abbreviations

1 acre = 43,560 sq. ft.

1 acre = One 40" row - 13,068 ft. long

1 acre = One 38" row - 13,724 ft. long

1 mile = 5,280 ft.

1 MPH = 88 ft./minute

Area of a circle = πr^2

π = 3.14 r = radius

Volume of a cylindrical tank = $\pi r^2 \times h$ = 3.14 X radius² X height

4 Qt. = 1 Gal.

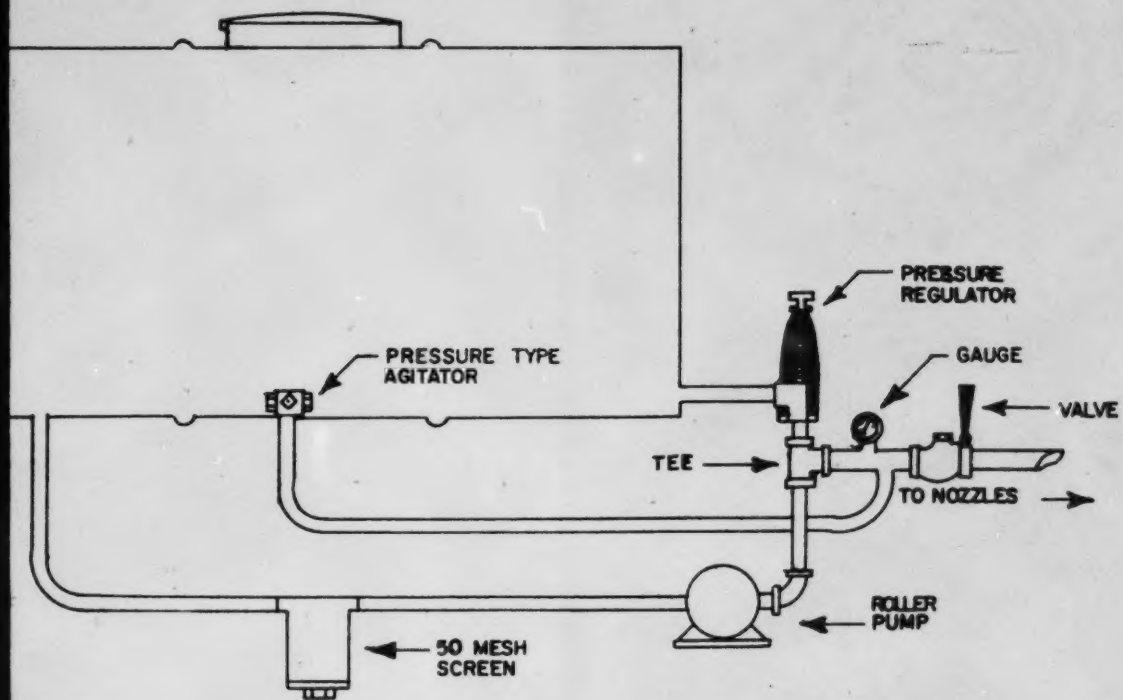
2 Pt. = 1 Qt.

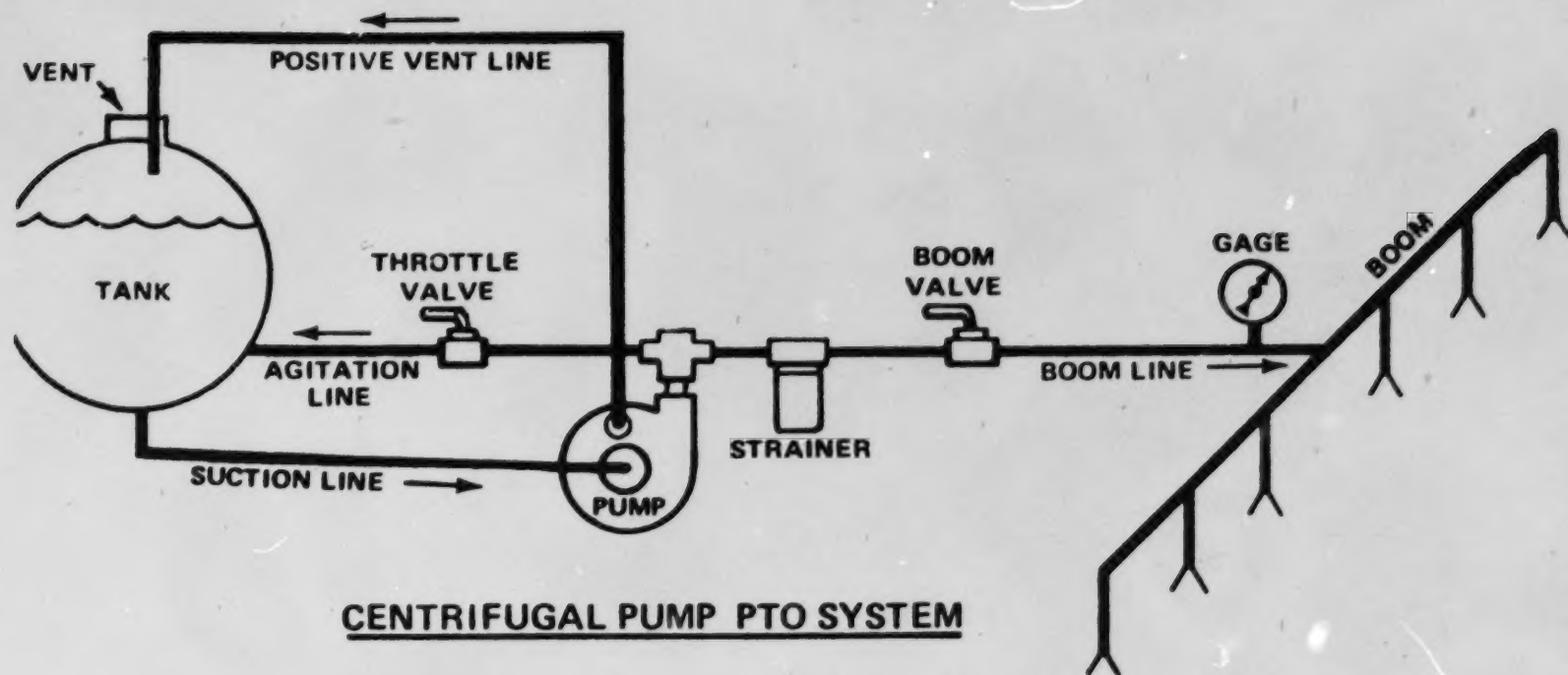
8 Pt. = 1 Gal.

16 Oz. = 1 Pt.

32 Oz. = 1 Qt.

LOW GALLONAGE SPRAYER





How to connect a sprayer with a piston pump

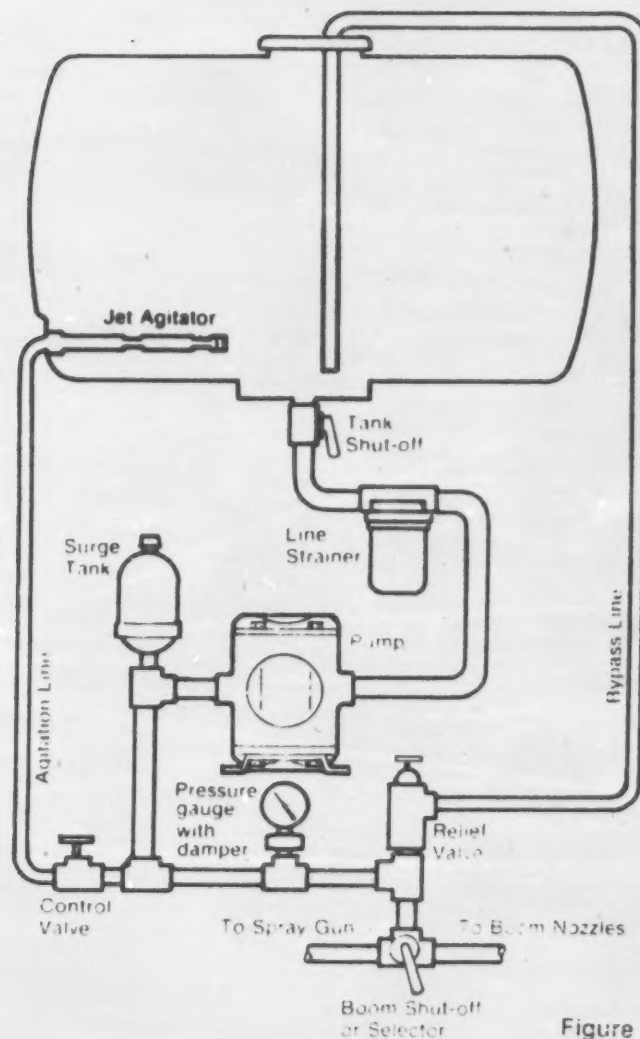
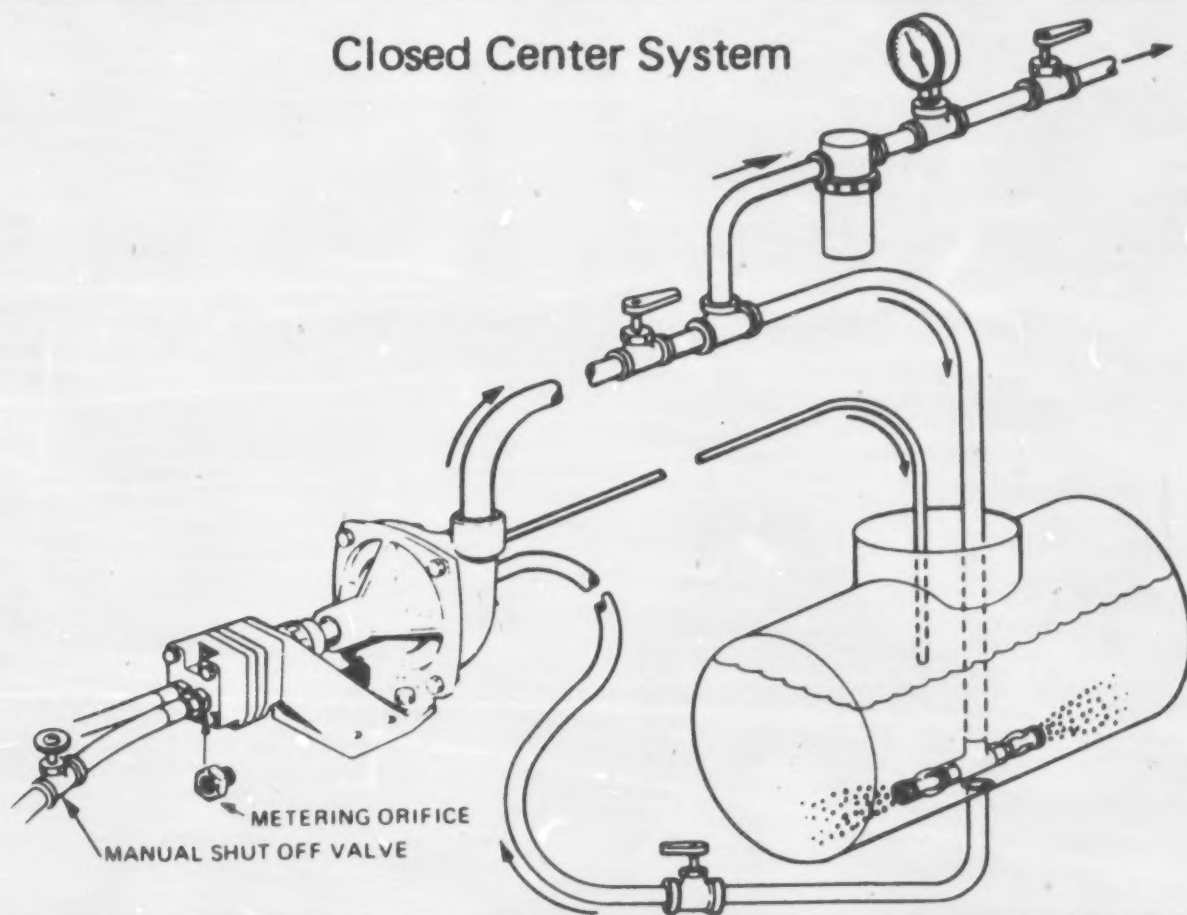


Figure 11

"CLOSED CENTER" TRACTOR HYDRAULIC SYSTEM



"OPEN CENTER" HYDRAULIC SYSTEM

OPEN CENTER SYSTEM

IMPORTANT: THIS LOOP WITH EXTERNAL CONTROL VALVE IS NOT USED WHEN HYDRAULIC MOTOR HAS BUILT IN BY PASS VALVE (SLOTTED SCREW LOCATED ON SIDE OF MOTOR)

REGULATING VALVE

HYDRAULIC OIL BY PASS LINE

CENTRIFUGAL PUMP

COUPLING

HYDRAULIC OIL RETURN LINE TO TRACTOR

HIGH PRESSURE
OIL LINE FROM
TRACTOR

HYDRAULIC MOTOR

SUCTION HOSE

POSITIVE VENT LINE

BY PASS HOSE

AGITATORS

OPTIONAL TANK
SHUT OFF VALVE

HIGH PRESSURE OIL VOLUME CONTROL VALVE

Useful Information for Calibration

The following information is related to applicator calibration and when referred to will provide some simplicity for calibration or calculations.

Abbreviations

GPA = Gallons per acre.

GPM = Gallons per minute.

MPH = Miles per hour.

W = Nozzle spacing (in boom spraying) or spray swath.
(in boomless spraying) in inches.

A = Acres

PSI = Pounds per square inch (gauge pressure)

Useful Formulas for Calibration

$$\text{GPM (Per Nozzle)} = \frac{\text{GPA} \times \text{MPH} \times \text{W}^*}{5940}$$

$$\text{GPA} = \frac{5940 \times \text{GPM}}{\text{MPH} \times \text{W}^*}$$

$$\text{MPH} = \frac{5940 \times \text{GPM}}{\text{GPA} \times \text{W}^*}$$

*W - Nozzle spacing (in boom spraying)
or spray swath (in boomless
spraying) in inches.

Vehicle Speeds

Speed in M.P.H. (miles per hour)	Time Required in SECONDS to Travel a Distance of		
	100 Feet	200 Feet	300 Feet
1.0	68	137	205
1.5	45	91	136
2.0	34	68	102
2.5	27	55	82
3.0	23	45	68
3.5	20	39	58
4.0	17	34	51
4.5	15	30	45
5.0	14	27	41

Application Speed vs Distance

1 Mi/Hr = 88 Ft/Min	9 Mi/Hr = 792 Ft/Min
2 Mi/Hr = 176 Ft/Min	10 Mi/Hr = 880 Ft/Min
3 Mi/Hr = 264 Ft/Min	11 Mi/Hr = 968 Ft/Min
4 Mi/Hr = 352 Ft/Min	12 Mi/Hr = 1056 Ft/Min
5 Mi/Hr = 440 Ft/Min	13 Mi/Hr = 1144 Ft/Min
6 Mi/Hr = 528 Ft/Min	14 Mi/Hr = 1232 Ft/Min
7 Mi/Hr = 616 Ft/Min	15 Mi/Hr = 1320 Ft/Min
8 Mi/Hr = 704 Ft/Min	16 Mi/Hr = 1408 Ft/Min

Rates of Flow

G.P.M.	Seconds to Collect 1 Quart	G.P.M.	Seconds to Collect 1 Quart
.05	300	.175	86
.06	250	.20	75
.07	214	.225	67
.08	188	.25	60
.09	167	.30	50
.10	150	.325	46
.11	136	.35	43
.12	125	.40	38
.13	115	.425	35
.14	107	.45	33
.15	100	.50	30

Additional Tables and Data Pertinent to Spray Calibration and Application

Gallons/Acre vs. Gallons/1,000 Sq. Ft.		1,000 Sq. Ft. of Area =
50 Gal/A = 1.148	Gal/1,000 Sq. Ft.	3 Ft. Swath 333.3 Ft. Long
100 Gal/A = 2.80	Gal/1,000 Sq. Ft.	4 Ft. Swath 250 Ft. Long
150 Gal/A = 3.44	Gal/1,000 Sq. Ft.	5 Ft. Swath 200 Ft. Long
200 Gal/A = 4.59	Gal/1,000 Sq. Ft.	6 Ft. Swath 166.6 Ft. Long
250 Gal/A = 5.75	Gal/1,000 Sq. Ft.	7 Ft. Swath 142.8 Ft. Long
300 Gal/A = 6.89	Gal/1,000 Sq. Ft.	8 Ft. Swath 125 Ft. Long
400 Gal/A = 9.18	Gal/1,000 Sq. Ft.	9 Ft. Swath 111.1 Ft. Long

Conversion TablesLinear Measure:

- 1 foot = 12 inches
- 1 yard = 3 feet
- 1 rod = 5.5 yards = 16.5 feet
- 1 mile = 160 rods = 1760 yards = 5280 feet

Square Measure:

- 1 square foot (sq. ft.) = 144 inches (sq. in.)
- 1 square yard (sq. yd.) = 9 sq. ft.
- 1 square rod (sq. rd.) = 272.25 sq. ft. = 30.25 sq. yd.
- 1 acre = 43,560 sq. ft. = 4,840 sq. yds. = 160 sq. rds.
- 1 square mile = 640 acres

Cubic Measure:

- 1 cubic foot (cu. ft.) = 1728 cubic inches (cu. in.) = 29.922 liquid quarts = 7.48 gallons
- 1 cubic yard = 27 cubic feet
- 1 acre-foot = 325,851 gallons
- 1 acre-foot = 2,718,144 pounds
- 1 acre-foot = 43,560 cubic feet

Liquid Capacity Measure:

- 1 tablespoon = 3 teaspoons
- 1 fluid ounce = 2 tablespoons
- 1 cup = 8 fluid ounces
- 1 pint = 2 cups = 16 fluid ounces
- 1 quart = 2 pints = 32 fluid ounces
- 1 gallon = 4 quarts = 8 pints = 128 fluid ounces

Weight Measure:

- 1 gallon of water = 8.33 pounds
- 1 pound (lb.) = 16 ounces
- 1 hundredweight (cwt.) = 100 pounds
- 1 ton = 20 cwt. = 2000 pounds

Rates of Application

- 1 ounce/sq. ft. = 2722.5 lbs./acre
- 1 ounce/sq. yd. = 302.5 lbs./acre
- 1 ounce/100 sq. ft. = 27.2 lbs./acre
- 1 pound/100 sq. ft. = 435.6 lbs./acre
- 1 pound/1000 sq. ft. = 43.6 lbs./acre
- 1 gallon/acre = 1/3 ounce/1000 sq. ft.

What is 1 PPM?

1 PPM = 1 drop in a 160 gallon tank
1 lb. in 500 tons
1 oz. in 3 1/4 tons
1 minute in 1.9 years
1 cent in \$10,000
1 inch in 1.6 miles

Charts and tables courtesy of: Department of Transportation, State of Florida

Pump Hook-up drawings courtesy of: Hypro

TOXICITY OF PESTICIDES

Certain chemicals predominately organic, are used as pesticides because they are toxic to various pests (insects, weeds and causal organisms of plant disease). Many of these chemicals are also toxic to nontarget organisms including man. Safe and, in fact, proper use depends in part on knowledge of toxic properties and a respect for the potential hazards associated with their use.

Toxicology is defined as the study of evaluating safety and injurious effects of chemicals and physical agents as observed in altering structure, function and response in living systems. A compound's toxicity is its inherent ability to injure living organisms. The ultimate toxic effect on a living organism is death, either due to a single dose or to continued administration of some lesser dose.

Accepted theory regarding the mode of action of organophosphorus and carbamate compounds relates to their function as cholinesterase inhibitors. Acetylcholine is a mediator of the transmission of nerve impulses at the junction of nerves and muscles, at sensory nerve endings and nerves that are involved in the regulation of vital body processes such as breathing, pulse rate and function of the gastrointestinal tract, for example. Following a nerve impulse, the acetylcholine molecule is split (hydrolyzed) in the presence of an enzyme (acetylcholinesterase) and the nerve or junction thus is returned to the normal state again capable of carrying an impulse. The enzyme (acetylcholinesterase) functions to prevent persistent "activation" of the nerve of junction. Certain chemicals including organophosphorus and many carbamate pesticides block the action of the enzyme (acetylcholinesterase) and acetylcholine accumulates causing a malfunction or overstimulation of the nerves or nerve junctions.

Manifestations of the failure of the nerves to function properly are (1) contraction of the pupil of the eye (miosis), (2) tightness of the chest, (3) increased bronchial (respiratory tract) secretions, (4) sweating, (5) tearing (lacrimation), (6) rapid pulse rate initially followed by a decrease in the pulse rate, (7) nausea, vomiting, abdominal pain and diarrhea, (8) involuntary urination, (9) muscle twitching, (10) cramps and (11) increased salivation. A lethal dose of a cholinesterase inhibiting organophosphorus compound is reported to produce death due to respiratory failure (asphyxia). Symptoms of carbamate poisoning are essentially the same as those produced by the organophosphorus compounds.

Clinically, poisoning due to cholinesterase inhibiting organophosphorus or carbamate pesticides is confirmed by measuring the cholinesterase activity of the blood plasma or of the red blood cells (erythrocytes). Special precautions are necessary in using the cholinesterase activity of blood plasma or of the

red blood cells as a measure of carbamate poisoning since the blocking action by carbamates is readily reversed by certain procedures involved in many of the more commonly employed estimation methods. Persons working with organophosphorus or carbamate pesticides known to be inhibitors of the enzyme acetylcholinesterase should consult with a physician concerning the possibility of measurement of blood cholinesterase activity as an estimate of exposure. Atropine is known to be useful as an antidote for poisoning by organophosphorus and carbamate acetylcholinesterase inhibiting compounds. Atropine relieves many of the symptoms. The release of the enzyme (acetylcholinesterase) from the blocking action of organophosphorus acetylcholinesterase inhibiting compounds is promoted by the use of 2-PAM(2-Pyridine aldoxime methochloride). In cases of organophosphorus poisoning, 2-PAM, used in conjunction with atropine, is often very effective. The oxime (2-PAM) should not be used in treating poisoning due to carbamate acetylcholinesterase inhibiting compounds.

Although the symptom-producing effect of organophosphorus poisoning is a result of blocked activity of the enzyme at the nerve or nerve ending, the enzyme also exists in tissue and blood. The enzyme of tissue and blood may serve as a buffer or reserve "tying up" much of the toxic material although some will affect the enzyme at the nerve or junction. Thus, the reduction of blood and tissue enzyme by repeated exposure to the poison reduces the reserve, and the critical enzyme at the nerve and nerve junctions is more readily affected (figure 1). Although repeated exposure to very small doses of organophosphorus insecticides is said to result in a "tolerance" to poisoning in rats and mice, one should not assume a similar reaction in man. Exposure of a significant nature is likely to produce less severe poisoning if the reserve is not depleted. Thus, even in the absence of noticeable effects, one should always attempt to minimize exposure. (Refer to Exposure - Protective Measures).

There are wide differences in toxicity to man and other warm-blooded animals within a given group of class of compounds, particularly those used as insecticides. For example, some organophosphorus insecticides are direct inhibitors of acetylcholinesterase, while others are inactive per se but are changed in a biological system to one or more secondary toxicants that are inhibitors. Therefore, the net toxic effect may depend on a combination of factors including the rates of activation and/or detoxification, penetration to the site of action and the affinity of the toxicant for acetylcholinesterase.

The principal effect of chlorinated hydrocarbon insecticides is on the central nervous system although the exact nature of the action is unknown. For a review of the mode of action of other pesticides, the reader is directed to the "Clinical Handbook on Economic Poisons" (Public Health Service Publication No. 476) available through the U. S. Government Printing Office.

There are numerous effects other than death that are very damaging to living systems. A familiar effect is that produced by thalidomide. Congenital malformation or teratism can result from diverting the course of normal fetal development. Such toxicity attributed to a chemical is termed teratogenicity.

Other commonly known expressions of toxicity are mutagenesis and carcinogenesis. Less severe, yet equally important toxic effects are hemolytic (blood) reactions, allergy, photosensitization, disruption of normal organ function, etc. Recognition of the multitude of possible toxic effects is necessary if one is to accurately appraise the hazard of a given chemical use.

Acute toxicity usually implies overwhelming intoxication producing gross symptoms or death. Chronic toxicity is not as easily defined, but generally refers to an illness or undesirable effect resulting from longterm, relatively low exposure. Toxicity, acute or chronic, may result from oral, dermal (through intact skin), or respiratory exposure alone or in combination. A fourth route of entry of pesticides into the body is through cuts, abrasions or other skin disruptions.

One method of measuring acute toxicity is to determine the chemical dosage that will, upon administration to a group of animals, kill one-half of the group. Thus, the figure LD₅₀ (lethal dose 50 percent) can be applied to oral and dermal exposure. Acute oral LD₅₀ values are generally available on most pesticides. Acute dermal LD₅₀ values are not as widely reported. The LD₅₀ value is usually expressed on a weight to weight basis, i.e., milligrams of chemical per kilogram of body weight for a given test animal. Other information generally specified in reporting LD₅₀ values includes species, strain, age and sex of the experimental animal, administration route, concentration of test material and vehicle used to administer the chemical.

Criteria for cataloguing pesticides by toxicity established in the Federal Insecticide, Fungicide and Rodenticide Act are as follows:

Highly toxic:	LD ₅₀ - 50 mg/kg or less
Moderately toxic:	LD ₅₀ - between 50-500 mg/kg
Low order toxicity:	LD ₅₀ - 500-5000 mg/kg
Comparatively free from danger:	LD ₅₀ - 5000+ mg/kg

A chemical with an LD₅₀ of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours to the bare skin of rabbits is considered highly toxic to man.

LC₅₀ is the term used to identify the concentration of a chemical in air that is fatal to 50 percent of the test animals when administered by continuous inhalation for 1 hour to both male and female rats or in some cases other species. A pesticide that is shown to exhibit an LC₅₀ value of 2,000 micrograms or less of dust or mist per liter of air or 200 parts per million or less by volume of gas or vapor is considered to be highly toxic to man.

In each case, the acute oral LD₅₀, dermal LD₅₀ and LC₅₀ is evaluated on the basis of death produced in 50 percent of the test animals within 14 days of the challenge.

Pesticides highly toxic to man as described in the above criteria generally include those pesticides termed class B poisons as defined by regulations of the U. S. Department of Transportation.

"Class B substances have been defined as those substances, liquid or solid (including pastes and semisolids), other than class A or class C poisons, which are known to be so toxic to man as to afford a hazard to health during transportation; or which, in the absence of adequate data on human toxicity, are presumed to be toxic to man because they fall within any one of the following categories when tested on laboratory animals:

1. Oral toxicity. Those which produce death within 48 hours in half or more than half of a group of ten or more white laboratory rats weighing 200 to 300 grams at a single dose of 50 milligrams or less per kilogram of body weight when administered orally.
2. Toxicity on inhalation. Those which produce death within 48 hours in half or more than half of a group of ten or more white laboratory rats weighing 200 to 300 grams, when inhaled continuously for a period of 1 hour or less at a concentration of 2 milligrams or less per liter of vapor, mist or dust provided such concentration is likely to be encountered by man when the chemical product is used in any reasonable foreseeable manner.
3. Toxicity by skin absorption. Those which produce death within 48 hours in half or more than half of a group of ten or more rabbits tested at a dosage of 200 milligrams or less per kilogram of body weight, when administered by continuous contact with the bare skin for 24 hours or less.

The foregoing categories shall not apply if the physical characteristics or the probable hazards to humans as shown by experience indicate that the substances will not cause serious sickness or death, etc..."

LD₅₀ values have become the universally accepted means of expressing toxicity. Acute oral LD₅₀ values provide a means of comparing one chemical to another and thus a means of evaluating the relative toxicity of chemicals when administered orally. Many are and will be tempted to use the values in an absolute sense, i.e. direct extrapolation of LD₅₀ to man even to the point of calculating the LD₅₀ dose for man. The relevance of these animal values to man is questionable. Further assumption could lead to serious consequences. One should assume in the absence of information to the contrary, that the chemical is at least as toxic to man as it is to the most sensitive test animal. The following facts tend to support this conclusion as a guiding principle:

1. Variation exists between species.
2. Variation exists within species.
3. Variation exists between sexes.
4. The human population will include the very young, the old, the debilitated, the pregnant and those in varying degrees of diseased states.

5. Repeated exposure to chemicals may result in what might be termed a "conditioned" response.

A generally accepted uniform method for testing dermal toxicity is not evidenced in the available literature, although methods have been proposed. Considering the fact that such values (LD_{50} , LC_{50}) are valuable in a relative sense, testing uniformity may be as important as the precision of the method. Factors to be considered include:

1. Variation in dermal (skin) penetration rates between species
2. Variation within species
3. Skin condition
4. Animal condition
5. Environmental conditions (temperature and humidity)
6. Solvent in which the chemical is applied
7. Time in contact with skin

Toxicity vs. Hazard

A hazard of using a chemical is the danger it presents or possibility or probability that injury may result from using a substance. Hazard can be measured only in relation to practical conditions, although it can be predicted in part, at least, by the toxicity of the chemical in question. Estimating the degree of exposure is equally important in assessing or evaluating hazard.

Research has shown that dermal exposure to parathion, DDT, malathion, chlorthion and dinitro-ortho-cresol under practical conditions of agricultural or residual spraying is from two to 494 times as great as in respiratory exposure, even when only the face, neck and lower arms are exposed. According to Hayes, "there is no doubt that the measured dermal exposure of spraymen is adequate to the account for the majority of occupational poisoning by many newer pesticides." Hayes suggests also that oral exposure to pesticides during ordinary spraying has not been measured, but that the amount ingested in various ways, such as eating with unwashed hands, appears to be small in most instances. On the contrary, the poisoning incidence of children is usually associated with the ingestion of the pesticide resulting from improper storage of chemicals. Respiratory exposure can be very significant when spraying in closed areas with very small particulate spray such as a mist spray, dusts and materials that vaporize rapidly under normal conditions such as fumigants. Dermal exposure may also be significant route of exposure of those working in treated fields (field workers, insect scouts, etc.).

These comments generally are related to conditions in the sense of actual sign and symptom-producing exposures. Repeated small doses of certain pesticides, while possibly not producing immediate illness, can result in a slow progressive effect eventually reaching the point of producing an illness. In view of this, occupational exposure to any chemical should be minimized to the extent possible (Refer to section on Exposure-Protective Measures).

Summary

Information regarding the toxic effects of pesticides on humans is limited to that obtained through actual experiences (fortunately and notably few) and those extrapolations of animal data that can with proper knowledge of comparative toxicology, etc., be made by experienced and trained persons qualified to make such judgments.

There are numerous reports in the scientific literature of the acute oral LD₅₀ and several of acute dermal LD₅₀ and of acute LC₅₀. Ideally one should seek that information which has been obtained from the same laboratory under the same conditions when making comparisons. The author's expressed purpose has been to suggest important known factors for assessing the hazard of a given pesticides use. In summary, the following guidelines are suggested.

1. Gather all available toxicity data on the pesticide in question. Be sure to recognize the distinction between compound toxicity and formulation toxicity.
2. When information to the contrary is not available, assume the pesticide is at least as toxic to man as it is to the most sensitive test animal.
3. Anticipate as well as possible, the conditions of use including:
 - a. Age and general health of the applicator (particularly skin conditions)
 - b. Education level of the applicator
 - c. Formulation
 - d. Application equipment
 - e. Protective clothing and equipment
4. Consider the applicator's previous experience.
5. Consider immediate experiences (exposures) of the applicator to pesticides.
6. Accessibility to medical assistance.
7. Accessibility to water in case of spills or other accidental dermal exposures.

8. Antidotes.

9. In the case of accidental poisoning it is very helpful if the pesticide label information is immediately available to the attending physician.

Use LD₅₀ - LC₅₀ data as a guide to the relative toxicity of the pesticide. Within limits and under practical conditions there is very little distinction within the broad categories of toxicity in terms of estimating hazard. Information derived from acute toxicity studies is only an indication of the care necessary to protect the person who, occupationally or otherwise, will be exposed to the chemical. Used in proper perspective, such information can permit useful predictions of the comparative hazards of using a pesticide.

Acute oral LD₅₀ can be measured for almost any substance by resorting to forced administration in cases where experimental animals are not expected to consume an acute oral LD₅₀ dose. The LD₅₀ value of sucrose (sugar) in white rats has been determined to be approximately 35 grams/kg in the male and 30 grams/kg in the female. The acute oral toxicity of corn oil to white rats has been reported to be approximately 256 grams per kilogram administered in equal doses over a period of 5 days, (a single acute oral dose was not possible). A reported LD₅₀ of caffeine to white mice maintained under three environmental temperatures is illustrative of the need for uniformity of testing in determining LD₅₀ and at the same time, of the need to be informed in evaluating and using LD₅₀ values. Both warming and cooling of white mice have been reported to increase the toxicity of caffeine. In another case at the elevated temperature, the toxicity of a drug (dextroamphetamine) has been reported to be ten times less than at normal temperatures, whereas reducing the temperature resulted in a two to threefold increase in toxicity.

Dermal exposure is considered by many as the more common exposure route. Occupational poisoning by industrial and agricultural chemicals in California during 1960 involved absorption through the skin (percutaneous) as the probable exposure route in approximately 80 percent of the cases.

Reportedly, over 97 percent of the pesticide to which the body is subjected during most exposure situations and especially to applicators of liquid sprays is deposited on the skin. Pesticides may be more readily absorbed through the skin on certain parts of the body than on others. In studies of the absorption of parathion, absorption has been found to vary depending on the site of the body. Absorption through the skin of the head and neck area was found to be greater than other sites tested with the exception of the skin of the armpit, the ear canal and the scrotum (Refer to section on Exposure - Protection Measures). Absorption through cuts, abrasions or other disruptions of the skin may be as much as eight times that through intact skin.

ESTIMATED RELATIVE ACUTE TOXIC HAZARDS OF PESTICIDES TO SPRAYMEN*

The estimates of hazards in this table are based primarily on the observed acute dermal and to a less extent oral toxicity of these compounds to experimental animals. Where it is available, use experience has also been considered. It should be noted that the classification into toxicity groups is both approximate and relative. These toxicity categories are not related to specific categories spelled out for label requirements.

Most Dangerous	Dangerous	Less Dangerous†	Least Dangerous
aldicarb, Temik® (C)‡ demeton, Systox® (OP) disulfoton, Di-Syston® (OP) mevinphos, Phosdrin® (OP) parathion (OP) phorate, Thimet® (OP) schadran, OMPA (OP) tepp (OP) thionazin, Zinphos® (OP)	aldrin (CH) Bidrin® (OP) carbophenothion, Trithion® (OP) DDVP, dichlorvos (OP) dieldrin (CH) dioxathion, Delnav® (OP) DNOC (N) DNOSBP (N) endrin (CH) EPN (OP) ethion, Nialate® (OP) methyl parathion (OP) nicotine (M) pentachlorophenol (M) phosphamidon, Dimecron® (OP) sodium arsenite (M) Zectran® (C)	azinphosmethyl, Guthion® (OP) BHC (CH) binapacryl, Morocide® (N) chlordane (CH) coumaphos, Co-Ral® (OP) diazinon (OP) dicapthion (OP) dichloroethyl ether (M) dimethoate, Cygon® (OP) endosulfan, Thiodan® (CH) fenthion, Baytex® (OP) heptachlor (CH) lead arsenate (M) lindane (CH) naled, Dibrom® (OP) oxydemetonmethyl, Meta-Systox®-R (OP) Ruelene® (OP) SMDC, Vapam® (M) trichlorfon, Dipterex®, Dylox® (OP) toxaphene (CH) VC-13	Aramite® (M) captan (M) carbaryl, Sevin® (C) chlorobenzilate (CH) 2,4-D (CH) DDD, TDE (CH) DDT (CH) dicofol, Kelthane® (N) Dilan® (CH, N) dinocap, Karathane® (N) diquat (M) IPC, propham (M) malathion (OP) maneb (M) methoxychlor (CH) mirex (CH) Morestan® (M) NAA (M) Perthane® (CH) piperonyl butoxide (M) ronnel, Korlan® (OP) rotenone (M) simazine (M) 2,4,5-T (CH) tetradifon, Tedion® (CH) thiram (M) zineb (M) ziram (M)

*Source of Data: Safety In the Use of Pesticides, Homer R. Wolfe, William F. Durham, Proc. 2nd Eastern Wash. Fertilizer and Pesticide Conf. Pullman; Washington State University, pp. 14-21, 1966. Through Pesticide Information and Safety Manual. University of California Agricultural Extension Service.

†The fumigant compounds acrylonitrile, D-D R, and Telone R have systemic toxicities which would indicate their placement under the "Less Dangerous" category. However, special note should be taken of the fact that the volatility of these compounds and their capacity to produce irritation of skin, eyes and other tissues indicate that appropriate caution should be exercised in their use. 70

‡The chemical class to which the pesticide belongs is designated as follows: C, carbamate; CH, chlorinated hydrocarbon; M, miscellaneous; N, nitro; and OP, organic phosphorus. 60

SUGGESTIONS FOR MINIMIZING BEE, FISH AND WILDLIFE LOSSES FROM PESTICIDES

It is impossible to use strong toxins out-of-doors at any time or place in Mississippi without endangering some populations of fish and wildlife. Therefore, the following comments should in no way be construed as acceptance or approval by wildlife conservationists of the widescale use of chemical sprays to control pest populations. From an ecological standpoint there is no "good" time or place to add strong toxins to the environment, especially on a broad scale. The more durable or persistent the chemical, the greater the danger. Consequently when applying pesticides use precautionary measures.

Follow the recommendations given below to help reduce mortality of fish and wildlife when pesticides are used.

1. Restrict the application of agricultural pesticides to agricultural fields where possible.
2. Follow all general and specific safety recommendations of the manufacturer and of state Cooperative Extension workers.
3. Treat only when necessary, using the pesticide least toxic to nontarget organisms that will still do the job.
4. Apply the least amount of pesticide(s) that will give effective control.
5. Make every effort to keep toxic materials on the target field and to avoid excessive drift. Avoid drift over streams or creeks. Do not spray when the wind velocity exceeds 5 to 10 m.p.h.
6. Do not apply pesticides directly to water (ponds, streams, rivers, or lakes) unless the label recommends the material for specific use in controlling a pest species found in water.
7. Avoid spraying the immediate watershed of a lake or pond with chemicals highly toxic to fish. Keep treated animals from going into fish-bearing waters or other water supplies until the spray has dried.
8. Do not treat ditches and channels that drain directly into farm ponds and other waters with chemicals toxic to fish or to warm-blooded animals that may drink the water.
9. Do not store or mix pesticides or liquid fertilizers where accidental spillage or release will drain directly into ditches and streams.
10. Do not use streams, ponds, or water-filled ditches for washing spray equipment or for the disposal of left-over pesticides or liquid fertilizers, particularly anhydrous ammonia.

11. Follow the U. S. Forest Service practice of delineating the infected areas to be treated and then mark off buffer zones bordering lakes, streams, and ponds. There should be a strip of grass at least 50 feet wide around the edge of a farm pond to reduce rapid runoff from the watershed.
12. Do not leave puddles of pesticides on hard surfaces--roads, concrete around buildings, and such. Desirable animals may drink them, or the pesticides may drain into water courses through prepared drainage systems.
13. Do not throw empty pesticide containers into water or leave them where they may be attractive to desirable animal species. Dispose of containers only in an approved manner. Burn paper bags or containers and avoid breathing in the smoke. Bury empty glass or metal containers.
14. Use granules instead of sprays or dusts wherever possible to prevent undesirable drift.
15. Use ground machinery for application near critical wildlife and aquatic areas. This equipment makes it easier to confine the chemicals to specific target areas.
16. Do not spray areas harboring dense populations of wildlife.
17. If at all possible, no direct applications or excessive drift of toxic materials should be permitted in wooded areas, because these areas usually contain the greatest abundance and variety of wildlife.
18. If possible, avoid treating habitats other than row crops or plowed fields between April 1 and June 1, and between September 1 and November 1. If treatment of other habitat is essential, use the chemical least toxic to wildlife.
19. In areas frequented by waterfowl and shorebirds, avoid treatments at any time the area is being frequented by waterfowl.
20. When using treated seed, do not leave spilled seed exposed. See that the seed is all well covered and not readily available to birds and mammals.
21. Disk soil insecticides in immediately upon application, both to avoid wasting insecticide and to prevent wildlife losses.
22. Use the most-selective insecticides at minimum dosage rates and avoid the large-scale use of persistent pesticides (chlorinated hydrocarbons) that are known to concentrate in living organisms.
23. Use the information in the checklist of insecticides or the attached table for the LD50 or LC50 values. Select those insecticides that will do the job but be less toxic to warm-blooded animals, including wildlife.

Insecticides, their common agricultural rates, LD50 to white rats and other animals, 24-hour LC50 to bluegills, and the calculated 24-hour LC50 in pounds of toxicant per water acre 3 feet deep.

Insecticide	White rats		Common agr. rate, (lb./A.)	Birds LD50 mg/kg	Fish LC50, ppb	Lb. toxicant per ft.-acre for bluegill LC50	Comments apply only to fish kill
	Approximate LD50, mg/kg.						
	Oral	Dermal					
Toxaphene ^{a/}	85	925	1.5	31	7	.02	<u>Extremely toxic to fish. Do not use in the vicinity of streams or ponds.</u>
DDT ^{a/}	115	2,510	...	595	7 ^{d/}	.02	
Azinphosmethyl (Guithion) ^{b/}	12	220	.5	75	8?	.02+	
Aldrin ^{a/}	49	98	1.0 to 1.5	6	10	.03	
Phorate (Thimet) ^{b/}	1	3	1.0	<1	10	.03	
Rotenone	75	940+	...	>1,414	24	.06	
Methoxychlor ^{a/}	5,000	6,000+	1.5	>2,000	31	.08	
Heptachlor ^{a/}	131	230	1.0 to 1.5	>2,000	35	.09	
Diazinon ^{b/}	92	680	1.0	4	54	.15	<u>Highly toxic to fish. Use great caution if applied in the immediate vicinity of streams and ponds.</u>
Parathion	12	14	.25 to .5	2	56	.15	
Lindane ^{a/}	89	950	...	900	61	.16	
Malathion ^{b/}	1,200	4,000+	1.0	167	120	.32	<u>Moderately toxic to fish. Use cautiously around streams and ponds. Avoid direct application of agri- cultural sprays to water insofar as fish are concerned.</u>
Demeton (Systox) ^{b/}	5	11	...	7	195	.53	
Naled (Dibrom) ^{b/}	250	800	.75	52	220	.59	
Carbofuran (Furadan)	5	885	.75 to 1.0	<1	240 ^{f/}	.60	
Carbaryl (Sevin) ^{c/}	675	4,000+	1.0 to 2.0	265	3,400	9.2	<u>Least toxic to fish. Reasonably safe to use around ponds or streams insofar as fish are concerned.</u>
Trichlorfon (Dylox)	595	2,000+	1.0	37	5,600	15.1	
Methyl parathion ^{b/}	19	67	.25 to .5	8	8,500	23.0	
D-methoate (Cygon) ^{b/}	215	505	.5	9	28,000	75.6	

^{a/} Chlorinated hydrocarbons, aldrin (as dieldrin), DDT, dieldrin, and heptachlor (heptachlor epoxide) are stored in fat and persist as residues. Methoxychlor is less readily stored, and its toxicity is lower than many others. Toxaphene does not tend to store and is rapidly excreted.

^{b/} Organic phosphates are usually not readily stored and break down in water. Some are highly toxic to warm-blooded animals.

^{c/} This carbamate is more residual than many phosphates but is relatively non-toxic to fish and wildlife.

^{d/} Lower than some studies show.

^{e/} Test bird: Mallard duck, ring-necked pheasant, bobwhite, or California quail. Toxicant administered as a single oral dose. Data from Denver Wildlife Research Center, Bureau of Sport Fisheries and Wildlife.

^{f/} Four-day exposure for LC50.

Some Characteristics of Animal Populations Helpful in Understanding the Wildlife-Pesticide Problem

First of all, it should be emphasized that we know little about the overall effects of any pesticide on any population of wild vertebrate animals. Certain general facts have been established, however. A considerable amount of data is available on the acute toxicity of various compounds to a variety of species in captivity. Also, a limited number of studies have been made on the rate of recovery of a population following one or more applications of a pesticide to an area. In populations of wild vertebrates some pesticides may produce great mortality both directly and indirectly through the food chain. It has been shown that persistent chemicals such as the chlorinated hydrocarbons are concentrated from the bottom of the food chain to the top so that animals at the top often accumulate heavy dosages of the toxin. As a result, whole populations may lose their reproductive capacity. Accumulations of pesticides through the food chain may already have reduced the reproductive capacity of the bald eagle, duck hawk, and other raptor populations both in Europe and North America, as well as certain species of fishes and fish-eating birds such as loons, cormorants, and pelicans.

While these discussions refer to all wild vertebrates in general, most of the remarks and examples will refer to birds. Because of their migratory and highly mobile nature, a greater number of birds are susceptible to poisoning from a single application of pesticides than are mammals.

Some Useful Facts about Pesticides and Fish Mortality

There are many causes of fish kills in ponds and streams including insecticides, herbicides, liquid fertilizers, barnyard wash, and numerous other factors which affect the supply of oxygen. Specifically some insecticides are much less toxic to fish than others. Proper selection and use of insecticides will reduce potential danger. We urge extreme care and caution in applying any insecticide near streams and ponds. Remember that even if only a very short section of a stream or dredge ditch becomes toxic, fish and other animals may be killed for many miles as the toxic slug flows downstream. When fish kill occurs, examine all possible causes, including pesticides.

The enclosed table may be of some help to you in answering questions about insecticides and fish kill. We compiled this information from several sources. In using this information, consider the stability of the compound, its tendency to store in fat, method and rate of use, affinity for soil particles, and solubility, as well as exact toxicity.

In the table, LC50 means the amount of pesticide in parts per billion needed to kill 50 percent of the test fish in a 24-hour period in the aquarium. This information applies to kill immediately after exposure and not to continued exposure at lower levels of concentration. Low levels of some pesticides may be stored in fat over a period of weeks. Theoretically this stored material could cause fish mortality if the fat was suddenly used under stress and the pesticides were redistributed throughout the fish's system.

LD50 is the number of milligrams (0.001 gram) needed per kilogram (1,000 grams) or 2.2 pounds of body weight to kill 50 percent of selected healthy laboratory test animals, usually white rats. Both oral and dermal toxicities are included in the table.

The LC50 and the rate per acre-foot of water is based on laboratory tests on 2-inch bluegills exposed to that concentration for 24 hours at a water temperature of 75°F. When exposed for 96 hours the concentration required to reach the LC50 was much lower. Toxicity varies greatly with fish species, chemical, and formulation of the chemical. The LC50 for naled (Dibrom) to rainbow trout was 70 ppb and for bluegill, 200 ppb; for trichlorfon (Dylox) it was 28,000 ppb for trout and 5,600 ppb for bluegill. Thus this table serves only as a guide. Bluegills, popular Mississippi fish species, were used as a guide rather than trout.

Some Facts about Pesticides and Bees

Bees are highly important as pollinators of tree fruits, pumpkins, clovers, cantaloupes, watermelons, cucumbers, squash, and other crops. Some of our common insecticides are highly poisonous to honey bees, alkali bees, bumble bees, and many other beneficial insects. Efficient management of control programs and of bees can do much to reduce loss of bees through necessary agricultural pest-control operations. Relating spraying operations to knowledge of daily bee activity, insecticide toxicity, plant maturity, and spray drift will reduce bee losses and may mean the difference between a satisfied producer and one faced with a lawsuit.

If informed of intended pesticide applications that could damage bees, a beekeeper may be able to protect his colonies to some extent. The chief apiary inspector will assist in locating or notifying beekeepers whose bees are endangered. In some cases, local county Extension advisers can also be of assistance.

Relative Toxicity of Pesticides to Honey Bees

Pesticides differ greatly in their effect on honey bees. The formulation of the material plays an important role in its toxicity to bees. In general, sprays are safer than dusts, and emulsifiable concentrates are less toxic than wettable powders. Granular materials usually are not hazardous to bees.

Fungicides, acaricides (miticides), herbicides, and blossom thinners are relatively nontoxic. These materials and the insecticides can be placed in three groups in relation to their effects on bees--those highly toxic, those moderately toxic, and those relatively nontoxic.

Insecticides Highly Toxic to Bees

This group includes materials that kill bees on contact during application and for one or more days after treatment. Bees should be moved from the area if highly toxic materials are used on plants the bees are visiting. This group includes:

aldrin
 arsenicals
 azinphosethyl (Ethyl Guthion)
 azinphosmethyl (Guthion)
 Azodrin
 Banol
 Baygon
 BHC
 Bidrin
 Bomyl
 carbaryl (Sevin)
 carbofuran (Furadan)
 Chlordane
 Ciodrin
 Dasanit
 diazinon
 dicapthion
 dichlorvos (Vapona)(DDVP)^{a/}
 dieldrin
 dimethoate (Cygon)
 dinitrobutylphenol (DNOSBP)
 Dursban

EPN
 fenthion (Baytex)
 Gardona
 heptachlor
 Imidan
 Lannate
 lindane
 malathion
 malathion ULV
 Matacil
 Metacide
 methyl parathion
 mevinphos (Phosdrin)^{a/}
 Mobam
 naled (Dibrom)^{a/}
 parathion
 phosphamidon (Dimecron)
 Pyramat
 Telodrin
 Temik
 Zectran
 Zinophos

Insecticides Moderately Toxic

These materials can be used with limited damage to bees if not applied over bees in the field or at the hives. Correct dosage, timing, and method of application are essential. This group includes:

Abate
 carbophenothion (Trithion)
 Carzol
 coumaphos (Co-Ral)
 DDT
 demeton (Systox)
 Dimetilan
 disulfotan (Di-Syston)
 endosulfan (Thiodan)
 endothion
 endrin

Galecron (Fundal)
 methyl demeton (Meta Systox)
 mirex
 oxydemetonmethyl (Meta Systox R)
 Perthane
 phorate (Thimet)
 phosalone (Zolone)
 Pyramat
 ronnel
 tartar emetic

^{a/} Short residual activity. Can usually be applied safely when bees are not in flight. Do not apply over hives.

Insecticides Relatively Nontoxic

Materials in this group can be used around bees with few precautions and a minimum of injury to bees. This group includes:

Relatively Nontoxic Insecticides

Acarol	methoxychlor
allethrin	Morestan
Aramite	nicotine
<u>Bacillus thuringiensis</u>	Omite
binapacryl (Morocide)	oil sprays (superior type)
Bordeaux mixture	ovex
Chlorbenside (Mitox)	Pentac
chlorobenzilate	Plictran
chloropropylate	Pyrethrum
dicofol (Kelthane)	rotenone
Dilan	sabddilla
Dimite (DMC)	Strobane
dioxathion (Delnav)	Sulphenone
ethion (Nialate)	TDE (Rhothane)
fenson (Murvesco)	tetradifon (Tedion)
Kepone	toxaphene
Lethane	trichlorfon (Dylox, Dipterex)
Lovoal	

Relatively Nontoxic Fungicides*

bordeaux mixture	folcid (Difolatan)
captan	folpet (Phaltan)
copper oxychloride sulfate	glyodin (Glyoxide)
copper 8-quinolinolate	maneb (Manzate)
copper sulfate	Mylone
copper oxide	nabam (Parzate)
Dexon	Polyram
dichlone (Phygon)	sulfur
dinocap (Karathane)	thiram (Arasan)
dodine (Cyprex)	zineb (Parzate)
Dyrene	ziram (Zerlate)
ferbam (Fermate)	

Relatively Nontoxic Herbicides*

amitrole	MCPA
CDAA (Randex)	monuron
CDEC (Vegelex)	NPA
dalapon	paraquat
dicamba (Banvel-D)	Planavin
diquat	sesone
diuron (Karamex)	simazine
EPTC (Eptam)	2,3,6-TBA (Trysben)
EXD (Herbisan)	2,4-D
IPC	2,4,5-T

Relatively Nontoxic Defoliant*

DEF	PREP
merphos (Folex)	

Some Additional Points to Remember

1. Prevention of bee losses is the joint responsibility of the spray operator, the farmer, and the beekeeper. Before spraying is done, the beekeeper should be notified in ample time to allow him to arrange for protection or movement of his colonies.
2. Sprays generally are less hazardous to bees than are dusts.
3. Late evening and early morning spray treatments (after 9 p.m. DST and before dawn, 3 a.m.) will reduce bee death losses.
4. Aircraft applications of technical/low volume malathion are HIGHLY poisonous to bees. This LV treatment should be used chiefly on range-lands for grasshopper control.
5. Ground sprayer treatments usually are less severe on bees than are aircraft applications.
6. Spraying or dusting while bees are active in the fields will increase bee kills.
7. Treatment over hives when bees are clustered outside the hive during hot weather increases bee kill.
8. Drift to neighboring fields in blossom, or to adjacent blossoming weeds and wild flowers, may result in substantial bee poisoning.

*Most fungicides, herbicides, and defoliant are relatively nontoxic.

9. Bees located in or very near fields before pesticide treatment may sustain serious death losses. Bees moved into fields and orchards after spraying is completed may suffer little loss.
10. For safest applications around bees, use the recommended amount of the safest pesticide to bees which can be expected to accomplish effective control of the pest concerned.
11. Bees fly most actively at temperatures above 55°F. Spraying when temperatures stay below 55° will do little harm to bees.

EMERGENCY PROCEDURE FOR HANDLING
ACCIDENTAL SPILLS OF CLASS B POISON PESTICIDE CHEMICALS

Pesticide Safety Team Network

The National Agricultural Chemicals Association has formed a Pesticide Safety Team Network to minimize the risk of injury from accidental spillage or leakage of Class B poison pesticides.

A central telephone number - (513) 961-4300 - in Cincinnati, Ohio is monitored on a 24-hour basis. Nine association members--Chevron, Shell, Stauffer, Chemagro, Diamond Shamrock, Velsicol, Niagara, Union Carbide and Monsanto--are participating in the program by cooperatively furnishing personnel, equipment and expertise for the prompt and efficient clean-up and decontamination of Class B poison pesticides involved in a major accident. More than 40 safety teams currently make up the network.

Each participant has been assigned a specific area of the United States for which he acts as area coordinator. The area coordinator's responsibility is to receive from Telephone Central reports of any accident involving a Class B poison pesticide occurring in his area and act in one of several ways to make sure that the potential hazard to the public is reduced or eliminated.

Immediately following an emergency message from Telephone Central, the area coordinator communicates with the manufacturer or producer of the involved product and agrees on a procedure to follow. The person reporting the incident to Telephone Central is then contacted and given immediate steps to take. A safety team, if needed, is sent, either from the manufacturer or dispatched by the area coordinator from a roster of teams in his area.

What Are Class B Poisons?

Class B poisons are defined in the Code of Federal Regulations, Title 49-Transportation, parts 170-189, Section 173.343 as follows:

173.343 less dangerous poisons, class B. liquid or solid, poison label; definition.

"(a) For the purposes of parts 170-189 of this chapter and except as otherwise provided in this part, class B poisons are those substances, liquid or solid (including pastes and semisolids), other than class A or class C poisons, which are known to be so toxic to man as to afford a hazard to health during transportation; or which, in the absence of adequate data on human toxicity, are presumed to be toxic to man because they fall within any one of the following categories when tested on laboratory animals:

(1) Oral toxicity. Those which produce death within 48 hours in half or more than half of a group of 10 or more white laboratory rats weighing 200 to 300 grams at a single dose of 50 milligrams or less per kilogram of body weight, when administered orally.

(2) Toxicity on inhalation. Those which produce death within 48 hours in half or more than half of a group of 10 or more white laboratory rats weighing 200 to 300 grams, when inhaled continuously for a period of 1 hour or less at a concentration of 2 milligrams or less per liter of vapor, mist or dust, provided such concentration is likely to be encountered by man when the chemical product is used in any reasonable foreseeable manner.

(3) Toxicity by skin absorption. Those which produce death within 48 hours in half or more than half of a group of 10 or more rabbits tested at a dosage of 200 milligrams or less per kilogram body weight, when administered by continuous contact with the bare skin for 24 hours or less.

(b) The foregoing categories shall not apply if the physical characteristics or the probable hazards to humans as shown by experience indicate that the substances will not cause serious sickness or death. Neither the display of danger or warning labels pertaining to use nor the toxicity tests set forth above shall prejudice or prohibit the exemption of any substances from the provisions of parts 171-179 of this chapter."

Economic Poisons Highly Toxic to Man

Regulation under present federal law (The Federal Insecticide, Fungicide and Rodenticide Act) defines economic poisons highly toxic to man as follows:

362.8 Economic poisons highly toxic to man.

"(a) Economic poisons which fall within any of the following categories when tested on laboratory animals as specified in subparagraphs (1), (2) or (3) of this paragraph are highly toxic to man or contain substances or quantities of substances highly toxic to man within the meaning of the Act (such economic poisons being hereinafter in this part referred to as economic poisons highly toxic to man): Provided however, that the Director may, upon application and after opportunity for hearing, exempt any economic poison which is in any of these categories, but which is not in fact highly toxic to man, from the requirements of the Act and the regulations in this part with respect to economic poisons highly toxic to man:

(1) Oral toxicity. An economic poison which has a single dose LD₅₀ of 50 milligrams or less per kilogram of body weight when administered orally to both male and female rats which have been fasted for a period of 24 hours (or to other rodent or nonrodent species specified by the Director); or

(2) Toxicity on inhalation. An economic poison which has an LC₅₀ of 2,000 micrograms or less of dust or mist per liter of air or 200 parts per million or less by volume of a gas or vapor, when administered by continuous inhalation for 1 hour to both male and female rats (or to other rodent or nonrodent species specified by the Director), if the Director finds that it is reasonably foreseeable that such concentration will be encountered by man; or

(3) Toxicity by skin absorption. An economic poison which has an LD₅₀ of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours with the bare skin of rabbits (or other rodent or nonrodent species specified by the Director).

(b) Tests on other species. Tests on other specified rodent or nonrodent species may be required by the Director with respect to individual economic poisons or to classes of economic poisons whenever he finds that tests on other species are necessary to determine whether an economic poison is highly toxic to man.

(c) Terms LD₅₀ and LC₅₀. An LD₅₀ as used in connection with oral toxicity and skin absorption toxicity tests specified in paragraph (a) (1) and (3) of this section is the dose and LC₅₀ as used in connection with inhalation tests specified in paragraph (a) (2) of this section is the concentration which is expected to cause death within 14 days in 50 percent of the test animals so treated.

(d) Toxicity based on human experience. If the Director finds, after opportunity for hearing, that available data on human experience with any economic poison indicate a toxicity greater than that determined from the above described tests on animals, the human data shall take precedence and, if he finds that the protection of the public so requires, the Director shall declare such an economic poison to be highly toxic to man for the purposes of this act and the regulations thereunder."

Please note that the regulation established certain parameters under which the LD₅₀ and LC₅₀ values are to be determined. Thus, in attempting to fit an economic poison into one of the categories, the conditions under which the data were obtained must be known in order to make a valid judgment.

The label of every economic poison which is highly toxic to man as described by the preceding quoted regulation is required to bear the word "danger" along with the word "poison" in red on a contrasting background in immediate proximity to the skull and crossbones and an antidote statement, etc. Thus, the presence of the symbols and signal words identify economic poisons that probably fall within the Department of Transportation's description of a Class B poison.

RECORD KEEPING

Accurate and complete records contribute to the success of an agricultural enterprise.

The use of a pesticide application record (see sample sheets) will provide a permanent record of purchase dates, application dates, types of equipment used, weather conditions and location of each pesticide application.

When considering the economic value of accurate, properly timed pesticide application, present regulations regarding residues and varying susceptibilities of different crops to certain pesticides and pesticide residues in soil, the importance of complete pesticide application records is obvious.

Maintain accurate records for safe and effective pesticide use in your agricultural operations.

A pesticide record helps to:

- . Determine amounts of pesticides needed
- . Reduce inventory carry-over
- . Improve pest control practices and avoid pesticide misuse
- . Compare applications with results obtained
- . Establish proper use when residue affects marketing your crop
- . Establish where an error was made, if such occurs
- . Establish proof of use or recommend procedures if indemnity payments are involved and are to be collected
- . Plan cropping procedure for next year

Keep the following information:

- . Crop and variety or animals treated
- . Location and acreage treated
- . Crop history including planting date and developmental stage
- . Date and time of application
- . Pesticide used, including the name, percent active ingredient, type of formulation, manufacturer, purchase date and lot number
- . Amount of pesticide per gallon or 100 gallons of dilution
- . Amount of dilution applied per acre
- . Calibration of equipment including nozzle size, pressure, throttle setting and gear
- . Weather conditions including temperature, wind direction and velocity, soil moisture conditions and relative humidity
- . Estimated total cost of application
- . Application results
- . When animals are treated, average weight, age and target pest

How to Keep Records

Carry a pocket notebook with you and record information as it happens. Don't rely on your memory. Transfer this information to a permanent record sheet which is kept in a safe place.

LIVESTOCK AND POULTRY PESTICIDE RECORD

Date	Animals Treated and Number	Average Weight	Age	Target Pest	Pesticide Name and Amount or Strength	Formulation Dust, E.C., W.P., "pour- on" etc. & Active Ingredient	Dilution Rate-Amt. of Pesti- cide per gallon	Total Amount of mater- ial	Est. Total Cost of Application	Remarks or Results

CROP PESTICIDE RECORD

Crop and Variety: _____ Planting Date: _____

Seed Source and Lot No. _____ Pesticide: _____ Date of purchase _____

Field: _____ Acreage: _____ Lot number _____

Date and time of application	Pesticide name, Manufacturer, % active ingredient and formulation (Granule, E.C., W.P., etc.)	Amount of pesticide per gal. or 100 gal. of dilution	Amount of dilution applied per acre	Calibration of Equipment	Weather Conditions	Est. Total cost of application	Remarks or Results
				Nozzle size: _____ Pressure: _____ Throttle setting: _____ Gear: _____	Temp. _____ Wind direction _____ Velocity _____ Soil Moisture conditions _____ Rel. Hum. _____		
				Nozzle size: _____ Pressure: _____ Throttle setting: _____ Gear: _____	Temp. _____ Wind direction _____ Velocity _____ Soil Moisture conditions _____ Rel. Hum. _____		
				Nozzle size: _____ Pressure: _____ Throttle setting: _____ Gear: _____	Temp. _____ Wind direction _____ Velocity _____ Soil Moisture conditions _____ Rel. Hum. _____		